# PHILOSOPHICAL

# TRANSACTIONS

OF THE

# ROYAL SOCIETY

OF

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FOR THE YEAR MDCCCXLV.

PART II.

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# ADJUDICATION of the MEDALS of the ROYAL SOCIETY for the year 1845 by the PRESIDENT and COUNCIL.

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The **COPLEY MEDAL** to Professor **THOMAS SCHWANN** of Louvain, for his Physiological Researches on the development of Animal and Vegetable Textures.

The **ROYAL MEDAL**, in the department of Astronomy, to **GEORGE BIDDELL AIRY**, Esq., Astronomer Royal, for his Paper entitled "On the Laws of the Tides on the Coasts of Ireland, as inferred from an extensive series of observations made in connexion with the Ordnance Survey of Ireland," published in the Philosophical Transactions for 1845.

The **ROYAL MEDAL**, in the department of Physiology, to **THOMAS SNOW BECK**, Esq., for his Paper entitled "On the Nerves of the Uterus," communicated to the Society in 1845, and ordered for publication in the Philosophical Transactions.

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The Paper appointed for the Bakerian Lecture in 1845, is Professor **DAUBENY'S** Memoir, entitled "On the Rotation of Crops."

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# PHILOSOPHICAL TRANSACTIONS.

## VII. *Memoir on the Rotation of Crops, and on the Quantity of Inorganic Matters abstracted from the Soil by various Plants under different circumstances.*

*By* Charles Daubeny, *M.D., F.R.S., &c., Honorary Member of the Royal English Agricultural Society, and Professor of Rural Economy in the University of Oxford.*

Received May 5,—Read May 22, 1845.

### *Contents.*

Introduction.

Part I.—On the quantity of produce obtained from the several plots of ground, each year throughout the period during which the experiments were continued.

Part II.—On the chemical composition of certain crops cultivated in the Botanic Garden, and on the amount of inorganic principles abstracted by them from the soil during the period the experiments were conducted.

Part III.—On the chemical composition of the soil in which the crops were grown, and on the proportion of its ingredients that was available for the purposes of vegetation.

### *Introduction.*

In laying before this Society an account of certain experiments which I have undertaken with the view of elucidating the principles upon which the advantage of a rotation of crops in husbandry depends, it may be proper that I should in the first instance state the circumstances under which they were commenced, as well as those which led me during the course of them to deviate in some respects from my original plan of proceeding.

During the prosecution of a set of researches which embraced a period of more than ten years, it might naturally be expected, that the views at first entertained would become modified, and that arrangements deemed sufficient for carrying out the original plan should appear unsatisfactory, in proportion as glimpses of other truths, than those which enlightened us at the outset, began to open upon the field of our inquiry.

Thus, when first I determined to apply a portion of the ground at my disposal to experiments having reference to the rotation of crops, the scientific world was generally impressed in favour of a theory which the celebrated De Candolle had so ingeniously and eloquently maintained; namely, that a soil became unfitted for supporting a second crop of any given plant, in consequence of the deleterious influence exerted upon it by juices excreted from the former one.

My original object therefore was,—first, to detect, if possible, the chemical nature of these supposed excretions; and secondly, to demonstrate their poisonous influence, by taking account of the expected diminution in the amount of the crop exposed to them, beyond that of another in which all the circumstances were the same, excepting the presence of the excretions in question.

To accomplish these two objects, it seemed sufficient to set apart a number of plots of ground uniform as to the quality and richness of its soil, planting one-half of the number year after year with the same species of crop until the land no longer produced it, and the other moiety with crops of the same description, succeeding one another in such a manner, that no one plot should receive the same twice during the period of the continuance of these experiments, or at least within a short interval of one another.

By weighing the produce of each plot, reduced to the same uniform condition of dryness, when it had arrived at maturity, I hoped to obtain data for computing, how much of the expected diminution might be referred to the exhaustion of the ground, and how much to the effect of excretions which the preceding crop had given out.

The influence of seasons indeed is in all these cases one of the most important elements in the calculation, yet by taking the average of a number of years, it was hoped that this source of error might be eliminated, and that whilst the mean of the crop obtained during the latter half of the period, as compared with that of the former half, might suggest the rate of exhaustion brought about by the annual demand made upon the resources of the soil, the difference between the *permanent* and the *shifting* crop in each instance might tend to show, in what degree the excretory function of each plant contributed to the result.

Assuming, therefore, on the faith of the then existing authorities, that soil would soon become deficient in the food which was required for the plants grown in it, and moreover that, even if not exhausted, it would become unsuitable to their growth, by being contaminated with the excretions from preceding crops, I conceived it unnecessary either to undertake an analysis of the soil itself at the commencement of my labours, or to inquire into the chemical constitution of the crops which I had obtained in the course of them.

Supposing, as was then too hastily assumed, that the composition of each vegetable was uniform, and had been already determined with sufficient precision, it should follow, that the amount of produce ought in itself to be an index of the quantity of inorganic matter abstracted from the soil, and that the number of crops obtained before the soil became effete would indicate the relative richness of the latter in those ingredients which were essential to the growth of the plant in question.

As I proceeded however in my experiments, I began to find, that both the postulates on which I had built were unsound, for neither was I able to detect any foreign organic matter in the soil, referable to the excretions of the crop which had grown in it[*], nor did I find that uniform difference between the shifting and the permanent crop, to the disadvantage of the latter, which I should have expected upon the principles of **De Candolle**'s theory.

Moreover, the researches of **Braconnot**, which have since been made known to the world, tended still further to throw doubt upon the truth of the facts on which the doctrine of excretion reposed, and when no longer swayed by the authority of the distinguished author of the theory in question, I perceived more clearly the difficulty of reconciling it with many facts or opinions that seemed current amongst agriculturists—such, for instance, as the growth of repeated crops of the most exhausting plants in certain rich alluvial, or newly settled countries; the continuance of a plant in a state of nature for ages in the same locality; and lastly, the views of **Liebig**, which went to prove, that the food of plants, so far as their organic constituents are concerned, is derived in all instances from the elements of air and of water.

No sooner, therefore, had I become suspicious as to the truth of the opinion which I had previously entertained as to the excretions from the roots of plants being capable of explaining the falling off of a crop after repetition, than I felt desirous of shaping my inquiries in such a manner as to ascertain, if possible, which of the other two conceivable explanations might deserve a preference; whether, for instance, the falling off of the crop was attributable to a failure in the soil of organic matters fitted for its nutrition, or of those inorganic materials which it equally required.

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[*] The soils that seemed to me most likely to afford indications of the presence of root excretions were those which had reared crops of poppies and of tobacco for several years in succession, the former plant containing, in morphia and meconic acid, products readily recognizable by chemical tests, and the latter one sufficiently so in nicotine.

I accordingly digested sifted portions of the soils, amounting in each instance to 5 lbs., in water for several hours.

The water drained off was evaporated, and then filtered.

The clear solution was first treated with sugar of lead, and the precipitate which fell was collected, and then dissolved in water acidulated with sulphuric acid. Had any meconic acid existed in combination with the lead, it would have been thus separated, the metal being precipitated along with the sulphuric acid with which it forms an insoluble salt.

None of the tests, however, usually employed for detecting meconic acid produced any effect,—chloride of iron dissolved in alcohol causing no red colour, and ammonio-sulphate of copper not being rendered green.

The liquor remaining after the introduction of the sugar of lead might have contained morphia held in solution by acetic acid. To detect it, the lead was in the first place thrown down by sulphuretted hydrogen, after removing which, the remaining solution, after being concentrated, was treated with ammonia, which produced a flocculent precipitate.

This, however, proved destitute of morphia, for neither was there any blue colour as produced by chloride of iron, nor any redness by nitric acid.

My attempts to detect nicotine in the soil in which tobacco had been grown proved equally ineffectual.

To determine this, it seemed necessary to appreciate, if possible, first, what materials the soil might have contained, both before the experiments commenced, and after their termination; and secondly, what might be the constitution of the plants themselves both in the permanent and the shifting crop, as compared with the normal condition of the same.

But as the experiments which I had instituted extended to no less than sixteen different species, my object being to select at least one out of each natural family, which contained amongst the plants included under it any of those usually cultivated for farm or garden purposes in this country, it seemed necessary to limit that part of the inquiry which involved the necessity of ash analysis to a portion only of the series, and accordingly, in the autumn of 1844, I selected from the crops grown in that year the following as the subjects of chemical examination, namely, Barley, Potatoes, Turnips, Flax, Hemp, and Beans.

Of each of these six plants, the shifting and permanent crops, after having been weighed in the usual manner, in order to estimate their relative amount, were reduced to ashes, so that the proportion of inorganic to organic matter might in the first instance be determined.

In consequence of the largeness of the bulk, iron vessels were necessarily employed for burning away the volatilizable parts, and hence a portion of peroxide of iron was always introduced into the ashes, which, being indefinite in quantity, rendered it necessary for me, in the subsequent analyses, to regard the whole of that ingredient as extraneous, and to reject it from the calculation. The same course was also pursued with respect to a certain variable amount of sand and charcoal always present in the ash, the former derived evidently from the soil, the latter from the carbonaceous matter of the vegetable, which could not be entirely removed by the combustion.

Of each of these six plants it appeared necessary to analyse at least three specimens—the first taken from the permanent crop, the second from the shifting one, the third from a piece of ground, not belonging to the spot at which the experiments were carried on, and under ordinary treatment, but corresponding as nearly as possible in natural character to the soil of the experimental garden.

Thus this part alone of the inquiry involved at least eighteen distinct analyses, an amount of labour, which, as I soon found, my other occupations precluded me from undertaking, and which I was glad to delegate to other hands.

I therefore esteemed myself fortunate in being able to secure the services of Mr. THOMAS WAY, a gentleman, who had for the last two years officiated as Assistant to Professor GRAHAM of University College, London, and who was recommended to me by that distinguished chemist as well-qualified for the task.

On him, therefore, the merit, as well as the responsibility, of this part of the inquiry must mainly devolve; all that I can lay claim to in this part of the subject as my own, is the having considered, in conjunction with him, the method of analysis which be ultimately adopted, and having made such preliminary trials on one of the crops which he afterwards analysed, as tended to satisfy me, that on those points in which the plan differs from that proposed by Dr. WILL, our method deserves the preference, on the score of convenience, if not with respect to accuracy.

In a case of this kind, experience alone can determine the degree of confidence which is due to the results obtained, but I ought not to withhold my own individual testimony to their fidelity, from having witnessed the manner in which they were conducted by Mr. WAY, his perfect familiarity with the processes which he pursued, and the scrupulous care taken by him in repeating every step in the investigation, which presented anomalous results, or appeared from any cause open to suspicion.

But to complete my design, an analysis of the soil, as well as of the crops which grew in it, was requisite, and to this subject therefore my attention was next directed.

Now, when we consider the nature of a soil in an agricultural point of view, or in reference to its suitableness for the growth of various kinds of vegetables, two questions naturally come before us; namely, what amount of ingredients capable of being assimilated in the course of time by the crops does it contain; and secondly, what is the amount of those which are present, in a condition actually available for their purposes, at the precise moment when the examination is undertaken.

Both the above points are obviously quite distinct from that of the total amount of ingredients actually existing in the soil, and hence some might be disposed to add to the labour of the two preceding investigations, that of ascertaining the whole of its constituents, whether in a state to be affected by the ordinary agents of decomposition, or not.

The latter question, however, seems to me to possess, with reference to the agriculturist, only a speculative interest, and when introduced into a Report intended for his use, may be more liable to mislead than to instruct, unless due caution be taken to point out to him, how much of each ingredient is to be regarded as inert, and how much of it as applicable to the future or present uses of the plant.

Let us take the case of a natural soil, composed of certain kinds of disintegrated lava, or even of granite, in which it is evident, that an actual analysis, conducted by means of fusion with barytes, or lead, or by those other processes which chemists employ for decomposing compounds of a refractory nature, would detect the presence of a large per-centage of alkali, not improbably of a certain amount of phosphate of lime, and in short would indicate an exuberant supply of all those ingredients which plants require for their support. Nevertheless a soil of this description, in consequence of the close union of the elementary matters of which it consists, and of the compactness of its mechanical texture, might be as barren, and as incapable of imparting food to plants, as an artificial soil composed of pounded glass is known to be, notwithstanding the large proportion of alkali which it contains.

Thus I have myself observed*, that the soil which covers the serpentine rock of Cornwall, a mineral consisting of—

| | |
|---|---|
| Silica | 43·07 |
| Magnesia | 40·37 |
| Alumina | 0·25 |
| Lime | 0·50 |
| Oxide of iron | 1·17 |
| Water | 12·45—Hisinger, |

contains so minute a proportion of magnesia, that in an analysis of a small sample I altogether overlooked its presence, in so great a degree does the mechanical texture of the rock, and the state of combination subsisting between its ingredients, preserve it from the decomposing action of the elements which tend to set loose its treasures.

Now it seems obvious, that whatever cannot be extracted from a soil by digestion in muriatic acid during four or five successive hours, must be in such a state of combination as will render it wholly incapable of imparting anything to a plant, for such a period of time at least as can enter into the calculations of the agriculturist; and moreover, that all which muriatic acid extracts, but which water impregnated with carbonic acid fails in dissolving, ought to be regarded as at present contributing nothing, although it may ultimately become available to its purposes.

I have therefore thought proper to distinguish between the actually available resources of the soil, and those ultimately applicable to the uses of the plant, designating the former as its *dormant*, and the latter as its *active* ingredients.

The portion dissolved after digestion in muriatic acid will contain both the dormant and the active; that taken up by water impregnated with carbonic acid will consist merely of the latter; the difference in amount between the two will therefore indicate the dormant portion of its contents.

The dormant and active portions may both be comprehended under the designation of its available constituents, whilst those which, from their state of combination in the mass, can never be expected to contribute to the growth of plants, may be denominated the passive ones.

Every soil, which is capable of yielding an abundant crop of any kind of plant after fallowing, must be assumed to possess in itself an adequate supply of all the ingredients necessary for its support in an available condition, but it is plain that these could not have existed in an active one, or such an interval of rest would not have been required for rendering them efficient.

Accordingly it is quite possible, that after ten years cropping, the soil of the experimental garden might still retain plenty of alkaline salts and phosphates, although what was ready to be applied to the uses of the plant had for the most part been absorbed by the crops previously obtained.

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* Lecture on the Application of Science to Agriculture, from the Journal of the Royal Agricultural Society of England, vol. iii. part 1.

With a view then to this part of the inquiry, I proposed to estimate, first, the amount of ingredients severally present in the soil which might sooner or later become available for the purposes of vegetation; and secondly, that of those principles which were in a state to be applied immediately to those uses. It would also have been instructive, to determine, by a comparative analysis of the soil, in the state in which it was before, and after the experiments had been instituted, the loss which had been occasioned by the crops in both these particulars; but as, from the reasons assigned, I had neglected to examine the identical soil of the experimental garden before the researches commenced, I was obliged to content myself with obtaining an approximation to its probable constitution, by selecting for examination that taken from a portion of the garden, which was immediately contiguous, but which had recently been manured, and had borne good crops.

Here also I was assisted by Mr. Way, who undertook the more laborious part of the inquiry, namely, that of determining the entire amount of the available constituents present in certain of the soils, leaving to me the task of ascertaining merely the nature of those which could be extracted by water.

The investigation therefore divides itself naturally into three heads; the first respecting the actual amount of the permanent and shifting crops each year obtained; the second, the chemical constitution of the ashes resulting from those which had been burnt for the purpose of examination; and the third, the nature of the actual as well as of the available ingredients of the soil in which the crops had been reared.

## PART I.

### *On the quantity of produce obtained from the several plots of ground, each year throughout the period during which the experiments were continued.*

The following plants were made the subjects of experiment:—

| | | |
|---|---|---|
| Spurge | *Euphorbia lathyris* | from 1835 to 1838 |
| Potatoes | *Solanum tuberosum* | from 1834 to 1844 |
| Barley | *Hordeum sativum* | from 1835 to 1844 |
| Turnips | *Brassica rapa* | from 1834 to 1844 |
| Hemp | *Cannabis sativa* | from 1835 to 1844 |
| Flax | *Linum usitatissimum* | from 1835 to 1844 |
| Beans | *Vicia faba* | from 1835 to 1844 |
| Tobacco | *Nicotiana Tabacum* | from 1834 to 1844 |
| Poppies | *Papaver somniferum* | from 1834 to 1844 |
| Buckwheat | *Polygonum fagopyrum* | from 1835 to 1844 |
| Clover | *Trifolium pratense* | from 1834 to 1844 |
| Oats | *Avena sativa* | from 1839 to 1844 |
| Beet | *Beta vulgaris* | from 1839 to 1844 |
| Mint | *Mentha viridis* | from 1835 to 1844 |
| Endive | *Cichorium endivia* | from 1835 to 1844 |
| Parsley | *Apium petroselinum* | from 1835 to 1844 |

As the experiments were carried on from 1834 to 1844 inclusive, it may be satisfactory to state in the first instance such of the meteorological characters of these years as may be gathered from the Register kept at the Radcliffe Observatory, relative to the mean temperature, or from my own observations made at the Botanic Garden, Oxford, as to the amount of rain.

| Year. | Inches of Rain. | Where observed. | Variation + or − (above or below) the mean of the period. | Mean temperature of the year. | Variation + or − (above or below) the mean of the period. |
|---|---|---|---|---|---|
| 1834. | 21·899 | Obs. | − 2·845 | 52·8 | +2·282 |
| 1835. | 26·182 | Obs. | + 1·438 | 51·5 | +0·982 |
| 1836. | 24·339 | Obs. | − 0·365 | 49·9 | −0·618 |
| 1837. | 21·900 | B.G. | − 2·844 | 50·0 | −0·518 |
| 1838. | 20·080 | B.G. | − 4·664 | 49·9 | −0·618 |
| 1839. | 32·720 | B.G. | + 7·976 | 51·2 | −0·318 |
| 1840. | 18·530 | B.G. | − 6·214 | 49·9 | −0·618 |
| 1841. | 35·275 | B.G. | +10·531 | 49·8 | −0·718 |
| 1842. | 23·490 | B.G. | − 1·254 | 50·8 | +0·282 |
| 1843. | 25·150 | B.G. | + 0·406 | 50·3 | −0·218 |
| 1844. | 22·621 | B.G. | − 2·123 | 49·6 | −0·918 |
| Total in eleven years. | 272·186 | .... | .... | 555·7 | |
| Average of eleven years. | 24·744 | .... | .... | 50·518 | |

The plots of ground set apart for the experiments were not exactly equal in point of size, but their square contents being known, it was easy to reduce the crops to one standard, and that of 100 square feet was selected as the most convenient.

In reporting to the Society the results, I shall therefore always suppose that reduction as being made, and shall set down what ought to have been the produce, supposing each plot to have measured exactly 100 square feet. In this statement I will begin with the only case in the whole series to which De Candolle's theory of excretions appears at all applicable; namely, that in which the plant experimented on was a species of Spurge, the *Euphorbia lathyris*.

In 1835 a luxuriant crop of this weed was obtained, amounting to about 18 lbs., but the next year the produce had dwindled almost to nothing, and in 1837, in which fresh plants were introduced, an equal failure took place.

Nor did any new plants start up in 1838, so that in 1839 the plot was sown with flax, barley, and beans, of all of which I obtained a tolerable yield.

This experiment therefore might be appealed to in support of De Candolle's views, as it would appear, that excretions had been emitted from the roots of the Euphorbia, which proved injurious to plants of the same species as those from which they had proceeded, but which exerted no such poisonous influence upon others not allied to them in organization; or, if it be objected, that during the course of 1838 the excretions might have become so far decomposed as to lose their poisonous character, still the failure of the second and third crops of Euphorbia would seem attributable to some deleterious influence exerted by the excretions of the antecedent crop, rather than to the ground having become exhausted, inasmuch as the latter, without being in the meanwhile enriched with manure, proved its ability to produce tolerable crops of other vegetables.

The acrid nature of the juices of the Euphorbia may possibly explain, why this plant should constitute an apparent exception to the rest, for it will be seen, that in all the other cases, the diminution in the amount of produce, consequent upon the continuation of the crop from year to year, was only such as might be supposed to result from a falling off in some one of those ingredients which were necessary for its development, and was not of a nature to indicate the existence of anything poisonous in the soil in which it grew*.

I shall therefore now proceed to state the amount of produce obtained during the several years from each of the remaining plants above enumerated, distinguishing the crop which was repeated year after year in the same plot of ground as the *permanent* one, and that which was grown successively in different parts of the garden as the *shifting* one.

1. *Solanum tuberosum.*—Ground not manured since 1833.

| Year. | Permanent crop. Weighed without having been dried, but merely cleaned from dirt. | Shifting crop. |
|---|---|---|
| 1836. | Plot No. 1.—After a crop of Turnips.<br>Tubers . . . 89·50 | After a crop of *Papaver somniferum.*<br>Tubers . . 84·00 |
| 1837. | Tubers . . . 59·5 | After a crop of *Cannabis sativa.*<br>Tubers . . 108·0 |
| 1838. | Tubers . . . 68·0 | After a crop of *Cannabis sativa.*<br>Tubers . . 68·5 |
| 1839. | Tubers . . . 59·0 | After a crop of *Polygonum fagopyrum.*<br>Tubers . . 132·0 |

1840. In this year it occurred to me, that it might be interesting to determine what difference, as to the amount of produce, would be produced by planting in one instance tubers from the crop obtained the year before in the same plot, and by employing in another those raised in some different locality.

The difference in quantity will be seen not to be very considerable.

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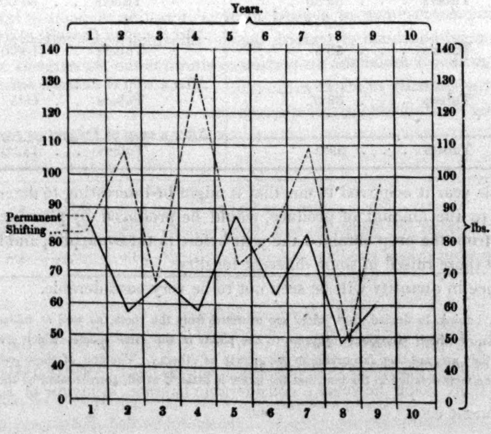
* It can hardly, I think, be denied, that juices are excreted from the roots, as well as taken up by them; the only question is, are these excretions injurious to the plants of the same species which grew in the soil afterwards, and if they are, are they favourable to the growth of others? The first of these positions may be countenanced by the facts detailed in the text, but the latter is little, if at all, corroborated by them.

| Year. | Permanent crop. No. 1.—Tubers from the same plot planted. | Permanent crop. No. 3.—Tubers from a different locality planted. | Shifting crop. |
|---|---|---|---|
| 1840. | Tubers . . 88½ | After *Euphorbia lathyris*, which had failed.<br>Tubers . . 90 | After *Linum usitatissimum.*<br>Tubers . . 72 |
| 1841. | Tubers . . 64 | Tubers . . 87½ | After *Linum usitatissimum.*<br>Tubers . . 81½ |
| 1842. | Tubers . . 82·5 | Tubers . . 94·0 | After *Vicia Faba.*<br>Tubers . . 110 |
| 1843. | Tubers . . 48·6 | Tubers . . 38·6 | After *Vicia sativa.*<br>Tubers . . 48·4 |
| 1844. | Tubers . . 61·0 | Tubers . . 57¾ | After *Hordeum sativum.*<br>Tubers . . 98·0 |
|  | Average of nine years.<br>Tubers . . 68·9 | . . . . . . . . . . | Average of nine years.<br>Tubers . . 89·1 |
|  | Average of the first five years.<br>Tubers . . 72·9 | Average of five years.<br>Tubers . . 74·77 | Average of the first five years.<br>Tubers . . 92·8 |

The following diagram may convey a clearer idea of the differences in the amount of the crops, and the relation between the permanent and shifting one.

POTATOES.



It is worth remarking, that the average of the shifting crops of potatoes corresponded very nearly to the amount obtained in the year 1844, from a bed of similar size, in a portion of the garden contiguous to that on which my experiments had been carried on, and which had been recently manured, the produce in this instance being 96·0 lbs., whilst the average of nine years in the other case was 89·1 lbs., and moreover that the produce of the last year, in which the crop succeeded one of barley, was not less than 98 lbs., thus apparently showing, that after so long a period of cropping, there was still a sufficient supply in the soil of those ingredients which were requisite for the due development of the plant.

An examination of samples of potatoes from the crop of 1844 proved, that the shifting crop contained more starch, and more of the woody fibre and other organic matters which belong to this vegetable, than either of the permanent ones; and that of the latter, the one grown in soil which had borne potatoes only five years, approached in these respects more nearly to the shifting, than that taken from the soil which had been cropped during ten years. The proportion of water in the two cases was not very different, but with respect to the inorganic matters, it was found that the remark held good.

Here the shifting crop yielded in a given amount of tubers the least, and the permanent crop the largest quantity of ash, as if the deficiency of organic matter had been made up by an increased quantity of that which was derived from inorganic sources. The nature of this latter portion will be stated when I proceed to detail the analyses performed by Mr. Way.

On examining a specimen of a good mealy description of potatoe taken from a garden in the neighbourhood of Oxford, the soil of which was similar to that of the experimental garden, I found the proportion of starch much the same as in the shifting crop, but the quantity of water greater.

The following is a tabular view of the results:—

| | Starch. | Fibrous matter. | Other solid matters. | Water. |
|---|---|---|---|---|
| | per cent. | | | |
| Good mealy kind of potatoe from a garden near Oxford . . | 13·00 | 5·90 | 5·6 | 75·5 |
| Shifting crop in experimental garden . . . . . . . . . | 13·67 | 9·76 | 5·7 | 71·9 |
| Permanent crop of five years' standing. . . . . . . . | 10·54 | 11·32 | 4·5 | 73·7 |
| Permanent crop of nine years' standing . . . . . . . | 9·11 | 9·76 | 8·8 | 72·4 |

### 2. *Hordeum sativum.*

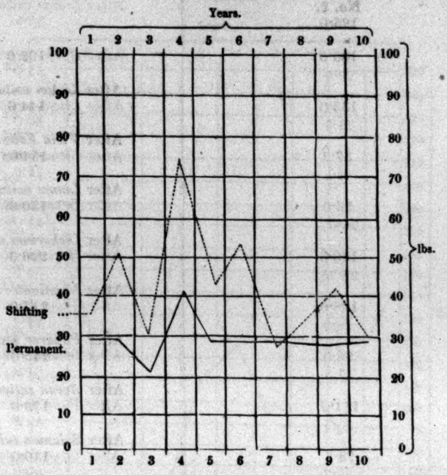
The next crop I shall notice is Barley, in which it will be perceived that, allowing for differences of seasons, the produce obtained during ten successive years was tolerably uniform, there being however a considerable balance in favour of the shifting over the permanent crop.

**The following are the results:—**

| Year. | Permanent crop. Produce in a dried state. | Shifting crop. Produce in a dried state. |
|---|---|---|
| | No. 4. | |
| 1835. | 29·0 | After *Linum usitatissimum.*<br>35·5 |
| 1836. | 29·0 | After *Apium petroselinum.*<br>51·0 |
| 1837. | 21·5 | After *Linum usitatissimum.*<br>30·0 |
| 1838. | 42·5 | After *Cichorium endivia.*<br>75·0 |
| 1839. | 28·0 | After *Brassica Rapa.*<br>41·0 |
| 1840. | 28·75 | After *Brassica Rapa.*<br>54·5 |
| 1841. | 28·0 | After *Vicia Faba.*<br>27·4 |
| 1842. | 27·5 | After *Solanum tuberosum.*<br>34·2 |
| 1843. | 26·5 | After *Papaver somniferum.*<br>42·5 |
| 1844. | 28·7 | After *Cannabis sativa.*<br>30·0 |
| | Average of ten years . . . 28·9 | Average of ten years . . . 42·1 |
| | Average of first five years . 30·0 | Average of first five years . 46·5 |
| | Average of last five years . 27·8 | Average of last five years . 37·7 |
| | Maximum in one year . . 42·5 | Maximum in one year . . 75·0 |
| | Minimum in one year . . 21·5 | Minimum in one year . . 30·0 |

The following Table will show the curve of their growth :—

BARLEY.



The quantity of barley produced in a contiguous piece of ground recently manured, was 39·4 lbs., being more than the average of the shifting crops, but about equal to the produce obtained the first year from the permanent one.

### 3. *Brassica Rapa.*

Next in the series are Turnips, in which the difference between the average of the shifting and permanent crop is very remarkable, namely as 176 to 100.

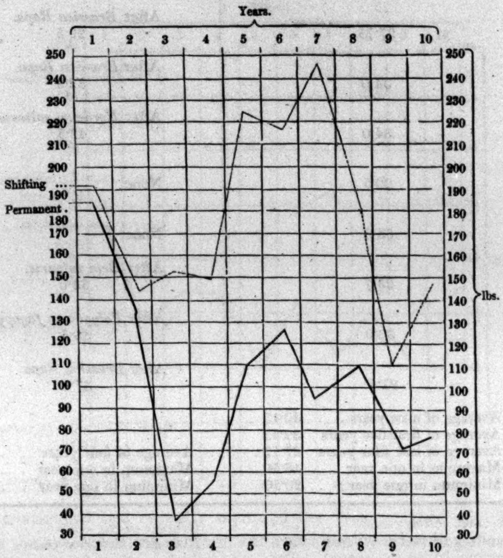
Nevertheless it will be seen, that even the latter did not sink below a certain amount when the seasons were tolerably favourable.

The following are the results :—

| Year. | Permanent crop. Produce in a green state. | Shifting crop. |
|---|---|---|
| 1834. | No. 2.<br>125·0 | |
| 1835. | 185·0 | 192·0 |
| 1836. | 133·0 | After *Linum usitatissimum.*<br>144·0 |
| 1837. | 37·2 | After *Vicia Faba.*<br>154·0 |
| 1838. | 56·0 | After *Linum usitatissimum.*<br>150·0 |
| 1839. | 110·0 | After *Cichorium endivia.*<br>226·0 |
| 1840. | 128·0 | After *Nicotiana rustica.*<br>217·0 |
| 1841. | 98·0 | After *Papaver somniferum.*<br>245·0 |
| 1842. | 111·0 | After *Avena sativa.*<br>179·0 |
| 1843. | 73·5 | After *Solanum tuberosum.*<br>110·0 |
| 1844. | 77·0 | After *Helianthus annuus.*<br>148·0 |
| | Average of ten years . . 100·8 | Average of ten years . . 176·5 |
| | Average of first five years 104·0 | Average of first five years . 173·0 |
| | Average of last five years . 97·5 | Average of last five years . 176·5 |
| | Maximum in one year . . 185·0 | Maximum in one year . . 245·0 |
| | Minimum in one year . . 37·2 | Minimum in one year . . 110·0 |

The following diagram will show the variations in their yearly produce :—

TURNIPS.



In the contiguous bed recently manured the produce was 152 lbs., a quantity about intermediate between the average of the shifting and permanent crops.

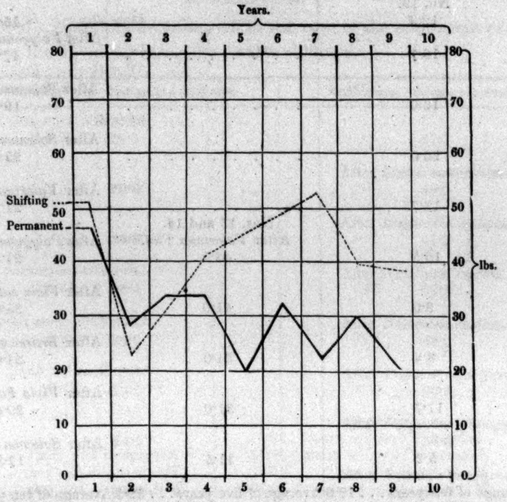
### 4. *Cannabis sativa.*

The next crop I shall notice, Hemp, presents a very uniform rate of produce during the whole period, nevertheless the shifting crop, which however was not grown during the years 1840 and 1841, presents a much larger produce than the permanent one, as will be seen by the following Table.

| Year. | Permanent crop. Dried in the sun. | Shifting crop. Dried in the sun. |
|---|---|---|
| 1836. | No. 17.<br>46·5 | After *Trifolium pratense*.<br>52·5 |
| 1837. | 27·75 | After *Brassica Rapa*.<br>22·5 |
| 1838. | 34·0 | After *Brassica Rapa*.<br>32·5 |
| 1839. | 34·0 | After *Hordeum sativum*.<br>42·5 |
| 1840. | 20·5 | None. |
| 1841. | 33·3 | None. |
| 1842. | 23·7 | After *Beta vulgaris*.<br>53·0 |
| 1843. | 30·0 | After *Polygonum fagopyrum*.<br>39·5 |
| 1844. | 21·5 | After *Brassica Rapa*.<br>37·6 |
|  | Average of nine years . . 30·13<br>Average of first five years 32·55<br>Average of last four years 27·12<br>Maximum in one year . 46·50<br>Minimum in one year . . 20·50 | Average of four years . . 30·0<br>Maximum in one year . . 52·5<br>Minimum in one year . . 22·5 |

The following diagram will show the variations in the yearly produce:—

HEMP.



In the contiguous bed recently manured the crop weighed 45·4 lbs., somewhat more than the average of the shifting, and considerably exceeding that of the permanent beds.

### 5. *Linum usitatissimum.*

Flax presents a gradual, though not an uniform, rate of deterioration, the shifting crop always standing in advance of the permanent one.

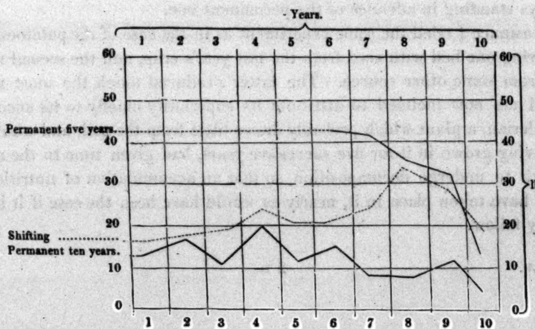
In this instance I tried the same experiment as in the case of the potatoes, namely, that of sowing one bed with seed from the last year's crop, and the second with seed obtained from some other source. The latter produced much the most abundant crop, but I am now inclined to attribute its superiority chiefly to its succeeding a crop of Valerian, a plant which probably draws little from the soil, and which consequently having grown in it for five successive years, had given time to the materials of the earth to undergo decomposition, so that an accumulation of nutritious principles may have taken place in it, nearly as would have been the case if it had been left entirely fallow.

The following are the results obtained :—

| Year. | Permanent crop of ten years' standing. Crop dried. | Permanent crop of five years, fresh seed. Crop dried. | Shifting crop. Crop dried. |
|---|---|---|---|
| | No. 19. | | |
| 1835. | 12·9 | | 15·8 |
| 1836. | 16·7 | . . . . . . . . . . | After *Polygonum fagopyrum.*<br>17·0 |
| 1837. | 12·0 | . . . . . . . . . . | After *Solanum tuberosum.*<br>19·8 |
| 1838. | 20·0 | . . . . . . . . . . | After *Solanum tuberosum.*<br>25·5 |
| 1839. | 13·75 | . . . . . . . . . . | After *Valeriana Phu.*<br>21·75 |
| 1840. | 16·5 | Nos. 13 and 14.<br>After *Valeriana Phu.*<br>43·5 | After *Polygonum fagopyrum.*<br>21·5 |
| 1841. | 9·0 | 41·0 | After *Vicia sativa.*<br>25·0 |
| 1842. | 8·4 | 34·0 | After *Brassica Rapa.*<br>34·0 |
| 1843. | 11·7 | 31·0 | After *Vicia Faba.*<br>29·6 |
| 1844. | 5·2 | 11·5 | After *Solanum tuberosum.*<br>17·8 |
| | Average of ten years . . . 12·6<br>Average of first five years 15·0<br>Average of last five years 10·4<br>Maximum in one year. . 20·0<br>Minimum in one year . . 5·0 | Average of five years . . . 32·5<br>. . . . . . . . . .<br>. . . . . . . . . .<br>Maximum in one year. . 43·5<br>Minimum in one year . . 11·5 | Average of ten years . . . 22·7<br>Average of first five years 19·9<br>Average of last five years 25·5<br>Maximum in one year. . 34·0<br>Minimum in one year . . 15·8 |

The following diagram will show the curve of their growth :—

**Flax.**



The contiguous manured crop weighed 22·2, rather less than the average of the shifting crops.

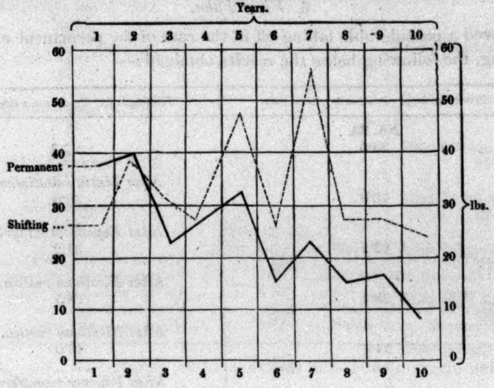
### 6. *Vicia Faba.*

Beans showed a considerable falling off in the case of the permanent crop, but not in the shifting, the following being the results obtained :—

| Year. | Permanent crop. Produce in a dried state. | Shifting crop. Produce in a dried state. |
|---|---|---|
| 1835. | No. 23.<br>38·0 | 27·7 |
| 1836. | 40·0 | After *Linum usitatissimum.*<br>39·0 |
| 1837. | 23·5 | After *Euphorbia lathyris.*<br>31·2 |
| 1838. | 28·4 | After *Nicotiana rustica.*<br>28·5 |
| 1839. | 34·0 | After *Nicotiana rustica.*<br>48·0 |
| 1840. | 16·5 | After *Papaver somniferum.*<br>26·5 |
| 1841. | 24·5 | After *Polygonum fagopyrum.*<br>56·0 |
| 1842. | 15·8 | After *Papaver somniferum.*<br>28·0 |
| 1843. | 17·1 | After *Avena sativa.*<br>28·0 |
| 1844. | 9·2 | After *Nicotiana rustica.*<br>24·0 |
| | Average of ten years . . . 24·7 | Average of ten years . . 33·6 |
| | Average of first five years 32·8 | Average of first five years . 34·8 |
| | Average of last five years 16·6 | Average of last five years . 32·5 |
| | Maximum in one year . . 40·0 | Maximum in one year . . 56·0 |
| | Minimum in one year . . 9·2 | Minimum in one year . . 24·0 |

The following represents the curve of their growth :—

BEANS.



In the contiguous manured bed the crop was only 27·1 lbs., not greatly exceeding the average of the permanent, and falling considerably short of that of the shifting crops.

### 7. *Nicotiana rustica.*

Tobacco is one of the plants which most strikingly illustrates the dependence of the crop upon manuring; the first year the produce being 178 lbs., whilst it sunk in six years' time to 17 lbs. The whole of this diminution, however, must not be set down to the deficiency of inorganic matter, since in subsequent years the produce became greater, although it never recovered its former rate.

In this instance the permanent presents a higher average than the shifting crop, but this seems attributable to the circumstance that in the latter instance the soil had been previously drawn upon by a crop of beans, whilst in the former it had been recently manured.

The following are the results :—

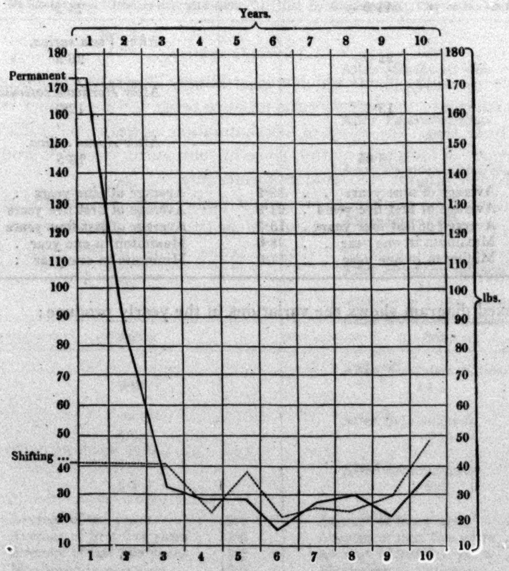
| Year. | Permanent crop. Produce nearly dry. | Shifting crop. Produce nearly dry. |
|---|---|---|
| 1834. | No. 9*a*.<br>172·0 | None. |
| 1835. | 83·0 | None. |
| 1836. | 33·0 | After *Apium petroselinum.*<br>42·0 |
| 1837. | 29·0 | After *Papaver somniferum.*<br>25·0 |
| 1838. | 29·0 | After *Euphorbia lathyris.*<br>38·0 |

## *Nicotiana rustica* (Continued).

| Year. | Permanent crop. Produce nearly dry. | Shifting crop. Produce nearly dry. |
|---|---|---|
| 1839. | No. 9*a*.<br>17·25 | After *Linum usitatissimum*.<br>22·5 |
| 1840. | 27·0 | After *Cichorium endivia*.<br>25·0 |
| 1841. | 30·0 | After *Apium petroselinum*.<br>24·0 |
| 1842. | 22·5 | After *Helianthus annuus*.<br>30·0 |
| 1843. | 37·8 | After *Brassica Rapa*.<br>49·0 |
| | Average of ten years . . . 48·0<br>Average of first five years . 69·2<br>Average of last five years . 26·9<br>Maximum in one year . . 172·0<br>Minimum in one year . . 17·2 | Average of eight years . . 32·0<br>Average of first four years . 32·0<br>Average of last four years . 32·0<br>Maximum in one year . . 49·0<br>Minimum in one year . . 22·5 |

The following diagram shows the variations of the crops :—

TOBACCO.



### 8. *Papaver somniferum.*

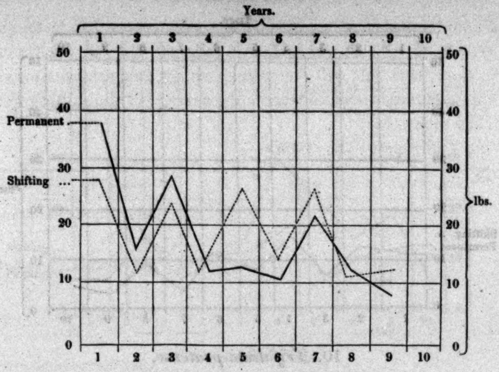
Poppies, although considered an exhausting crop, are said to be frequently grown for years in succession without any apparent decrease, but the results of my experiments serve to show, that this will not happen unless they are occasionally manured. It is remarkable how near in this instance the average of the shifting and permanent crops approaches each other.

The following Table shows the results:—

| Year. | Permanent crop. Dried in the sun. | | Shifting crop. Dried in the sun. | |
|---|---|---|---|---|
| | No. 5. | | | |
| 1836. | 38·0 | | After *Euphorbia lathyris.*<br>27·0 | |
| 1837. | 15·5 | | After *Cichorium endivia.*<br>11·0 | |
| 1838. | 29·0 | | After *Polygonum fagopyrum.*<br>24·0 | |
| 1839. | 13·0 | | After *Solanum tuberosum.*<br>13·0 | |
| 1840. | 14·0 | | After *Vicia Faba.*<br>26·5 | |
| 1841. | 11·0 | | After *Brassica Rapa.*<br>15·2 | |
| 1842. | 22·0 | | After *Vicia sativa.*<br>26·5 | |
| 1843. | 13·4 | | After *Hordeum sativum.*<br>12·0 | |
| 1844. | 8·65 | | After *Avena sativa.*<br>13·5 | |
| | Average of nine years . . | 18·2 | Average of nine years . . | 18·7 |
| | Average of first five years . | 21·9 | Average of first five years . | 20·3 |
| | Average of last four years . | 13·7 | Average of last four years . | 16·8 |
| | Maximum in one year . . | 38·0 | Maximum in one year . . | 27·0 |
| | Minimum in one year . . | 11·0 | Minimum in one year . . | 11·0 |

The annexed diagram shows the variations in the yearly produce:

POPPIES.

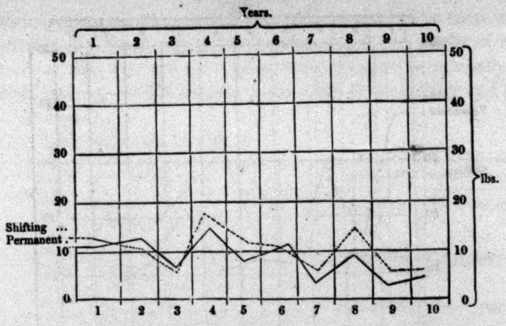


### 9. *Polygonum fagopyrum.*

Buckwheat, not being an exhausting crop, does not vary more than can be explained by differences of seasons and other contingent causes, the results being as follow :—

| Year. | Permanent crop. Produce in a dried state. | Shifting crop. Produce in a dried state. |
|---|---|---|
| 1835. | No. 25.<br>12·8 | 14·8 |
| 1836. | 14·0 | After *Mentha viridis.*<br>11·5 |
| 1837. | 6·0 | After *Valeriana Phu.*<br>5·7 |
| 1838. | 16·0 | After *Papaver somniferum.*<br>18·0 |
| 1839. | 9·25 | After *Vicia Faba.*<br>12·5 |
| 1840. | 11·5 | After *Hordeum sativum.*<br>11·5 |
| 1841. | 3·2 | After *Nicotiana rustica.*<br>5·5 |
| 1842. | 9·6 | After *Nicotiana rustica.*<br>14·1 |
| 1843. | 3·8 | After *Beta vulgaris.*<br>6·15 |
| 1844. | 5·1 | After *Beta vulgaris.*<br>6·6 |
| | Average of ten years . . . 9·1 | Average of ten years . . . 10·6 |
| | Average of first five years . 11·6 | Average of first five years . 12·5 |
| | Average of last five years . 8·7 | Average of last five years . 8·7 |
| | Maximum in one year . . 16·0 | Maximum in one year . . 18·0 |
| | Minimum in one year . . 3·2 | Minimum in one year . . 5·7 |

BUCKWHEAT.



### 10. *Trifolium pratense.*

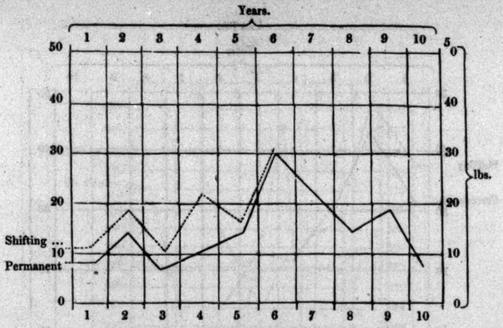
Red clover being a biennial, it was necessary to retain the shifting crop in the same bed for two years; and as the produce of the second year was in general larger than that of the first, the results can best be compared by stating the sum of each two years' growth.

| Year. | Permanent crop. Produce of two years. | Shifting crop. Produce of two years. |
|---|---|---|
| | No. 12. | |
| 1835. | 8·5 } 22·7 | 11·3 } 28·3 |
| 1836. | 14·2 | 17·0 |
| | | After *Mentha viridis.* |
| 1837. | 7·5 } 17·9 | 12·5 } 35·1 |
| 1838. | 10·4 | 22·6 |
| | | After *Euphorbia lathyris.* |
| 1839. | 14·0 } 44·0 | 17·0 } 48·0 |
| 1840. | 30·0 | 31·0 |
| 1841. | 22·3 } 37·5 | |
| 1842. | 15·2 | |
| 1843. | 18·8 } 26·3 | |
| 1844. | 7·5 | |

During the last four years it was not found convenient to introduce a shifting crop of clover.

The following curve represents the variations of the crop in the two cases.

CLOVER.



### 11. *Avena sativa.*

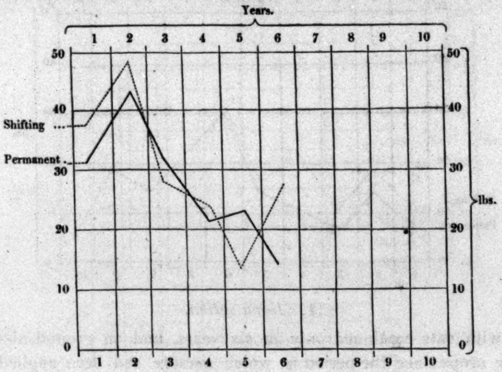
My trials with oats continued only for six years, and on ground already drawn upon by four crops since the period at which manure had been applied; the plot selected for the permanent crop having borne successively flax, beans, turnips, and hemp; that on which the corresponding crop in 1839 was raised, parsley, mint, and clover.

The produce therefore of the first year was in both cases moderate, and nearly uniform, but subsequently there was a greater diminution in the permanent than in the shifting crop, as will appear from the following Table:—

| Year. | Permanent crop. | Shifting crop. |
|---|---|---|
| 1839. | No. 20.<br>31·0 | After *Trifolium pratense.*<br>37·5 |
| 1840. | 44·0 | After *Trifolium pratense.*<br>49·0 |
| 1841. | 31·7 | After *Beta vulgaris.* 53·0<br>After *Trifolium pratense.* 28·5 |
| 1842. | 22·5 | After *Polygonum fagopyrum.*<br>24·4 |
| 1843. | 24·4 | After *Helianthus annuus.*<br>14·7 |
| 1844. | 14·6 | After *Vicia sativa.*<br>28·3 |
| | Average of six years . . . 28·0<br>Maximum in one year . . 44·0<br>Minimum in one year . . 14·6 | Average of six years . . . 32·4<br>Maximum in one year . . 49·0<br>Minimum in one year . . 14·7 |

The following curve will show the variations in the yearly produce.

OATS.



## 12. *Beta vulgaris.*

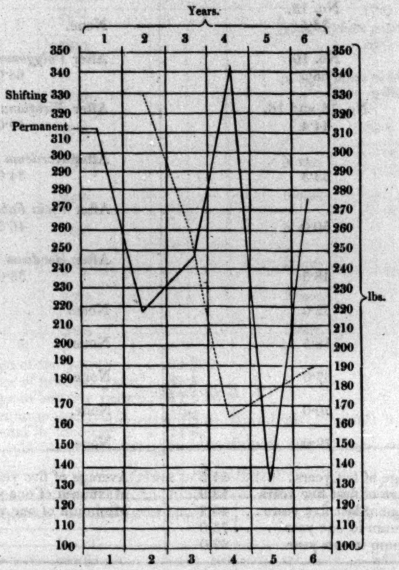
In the case also of the beet, the length of time during which the ground was cropped seems insufficient to lead to any decisive results, especially as the matters extracted from the soil by this plant are, compared to its bulk, inconsiderable.

The average of the shifting and permanent crops, it will be seen, does not vary materially, and what difference there is, seems in favour of the latter.

| Year. | Permanent crop. Weighed in a green state. | Shifting crop. Weighed in a green state. |
|---|---|---|
| 1839. | No. 11 *b.*—After *Papaver somniferum.*<br>312·0 | None. |
| 1840. | 217·0 | After *Cannabis sativa.*<br>330·0 |
| 1841. | 250·0 | After *Hordeum sativum.*<br>264·0 |
| 1842. | 344·0 | After *Avena sativa.*<br>173·0 |
| 1843. | 135·0 | 187·0 |
| 1844. | 278·0 | 200·0 |

The following diagram will show the variations in the annual produce:—

BEET.



13. *Cichorium endivia.* 14. *Mentha viridis.* 15. *Apium petroselinum.*

The three remaining crops, of Endive, Mint, and Parsley, were introduced into the series, from a wish to have one representative at least of the principal of those natural families, which supply us, with either plants useful for field or garden purposes, or with any of the commoner weeds which intrude themselves into our fields, it being conceived, that some interesting and useful results might be obtained, by watching the effect of their root excretions on plants of the same or of a different tribe.

Had it not been with a view to this theory, I should hardly have thought it worth while to experiment upon plants, which appear to draw comparatively so little from the soil, as the three now alluded to.

The following, however, were the results obtained:—

*Cichorium endivia.*

| Year. | Permanent crop. Dried in the sun. | Shifting crop. Dried in the sun. |
|---|---|---|
| 1834. | No. 15.<br>73·5 | None. |
| 1835. | No. 16.<br>68·5 | After *Polygonum fagopyrum.*<br>68·0 |
| 1836. | No. 15 and 16.<br>44·4 | After *Nicotiana rustica.*<br>49·0 |
| 1837. | 33·3 | After *Hordeum sativum.*<br>34·0 |
| 1838. | 50·0 | After *Vicia Faba.*<br>46·2 |
| 1839. | 48·5 | After *Hordeum sativum.*<br>38·0 |
| 1840. | 22·0 | None. |
| 1841. | 58·5 | None. |
| 1842. | 67·0 | None. |
| 1843. | 50·0 | None. |
| 1844. | 72·0 | None. |
|  | Average of ten years . . . 51·5<br>Average of first five years . 53·9<br>Average of last five years . 49·2<br>Maximum in one year . . . 73·0<br>Minimum in one year . . 22·0 | Average of five years . . 47·0<br>Maximum of one year . . 68·0<br>Minimum of one year . . 34·0 |

## *Mentha viridis.*

| Year. | Permanent crop. Produce in a dry state. | Shifting crop. Produce in a dry state. |
|---|---|---|
| | No. 21. | |
| 1835. | 21·9 | 17·0 |
| 1836. | 53·0 | After *Apium petroselinum.*<br>26·0 |
| 1837. | 38·0 | After *Apium petroselinum.*<br>9·25 |
| 1838. | 18·3 | 36·8 |
| 1839. | 26·75 | None. |
| 1840. | 24·5 | None. |
| 1841. | 16·8 | None. |
| 1842. | 18·7 | None. |
| 1843. | 12·8 | None. |
| 1844. | 16·5 | None. |
| | Average of ten years . . . 24·7<br>Average of first five years . 31·5<br>Average of last five years . . 17·8<br>Maximum in one year . . 53·0<br>Minimum in one year . . 12·8 | |

## *Apium petroselinum.*

| Year. | Permanent crop. Produce in a dried state. | Shifting crop. |
|---|---|---|
| | No. 27. | |
| 1835. | 64·25 | 74·0 |
| 1836. | 115·0 | After *Vicia Faba.*<br>208·0 |
| 1837. | 52·0 | After *Polygonum fagopyrum.*<br>61·0 |
| 1838. | 58·0 | After *Polygonum fagopyrum.*<br>68·5 |
| 1839. | 13·0 | After *Mentha viridis.*<br>32·5 |
| 1840. | 59·0 | After *Mentha viridis.*<br>83·0 |
| 1841. | 22·7 | None. |
| 1842. | 9·4 | None. |
| 1843. | 12·0 | None. |
| 1844. | 33·0 | None. |
| | Average of ten years . . 39·75<br>Average of first six years . 60·2<br>Average of last four years . 19·3<br>Maximum in one year . . 115·0<br>Minimum in one year . . 9·4 | Average of six years . . . 87·8<br>Maximum in one year . . 208·0<br>Minimum in one year . . 32·0 |

# Tabular View of Experiments on the Rotation of Crops.

| Name of the crop. | Whether planted in the same, or in different plots of ground. | No. of years during which the experiments were continued. | Amount of produce the first year. | Amount of produce the last year. | Highest amount of produce obtained during the whole period. | Year in which the highest amount of produce was obtained. | Smallest amount of produce obtained during the whole period. | Year in which the smallest amount of produce was obtained. | Average of the first five years. | Average of the whole period. | Crop obtained in 1844 from an equal space of ground previously well-manured. | General remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tubers. | Tubers. | Tubers. | | Tubers. | | Tubers. | Tubers. | Tubers. | |
| Potatoes (*Solanum tuberosum*) 1. | in the same | 9 | 89·50 | 61·0 | 89·50 | 1st year, viz. 1836 | 48·6 | 8th year, viz. 1843 | 72·9 | 68·9 | 88·5 | Merely cleaned from dust before weighing. |
| 2. | in different | 9 | 84·0 | 78·0 | 132·0 | 4th year, 1839, after Buckwheat | 48·4 | 8th year, 1843, after Vetches | 92·8 | 89·1 | ...... | |
| 3. | in the same | 5 | 96·0 | 57·75 | 96·0 | 1st year, 1840 | 58·6 | 4th year, 1843 | 74·77 | ...... | ...... | |
| Flax (*Linum usitatissimum*) 1. | in the same | 10 | 12·9 | 5·2 | 20·0 | 4th year, 1838 | 5·2 | 10th year, 1844 | 15·0 | 12·6 | 20·5 | Dried in the sun before weighing. |
| 2. | in different | 10 | 15·8 | 17·8 | 34·0 | 8th year, 1842, after Turnips | 15·8 | 1st year, 1835 | 19·9 | 22·7 | ...... | |
| 3. | in the same | 5 | 43·5 | 11·5 | 43·5 | 1st year, 1840 | 11·5 | 5th year, 1844 | 32·5 | ...... | ...... | |
| Beans (*Vicia Faba*) 1. | in the same | 10 | 38·0 | 9·2 | 40·0 | 2nd year, 1836 | 9·2 | 10th year, 1844 | 32·8 | 24·7 | 25·0 | Dried in the sun before weighing. |
| 2. | in different | 10 | 27·7 | 24·0 | 56·0 | 7th year, 1841, after Buckwheat | 24·0 | 10th year, 1844, after Tobacco | 34·8 | 33·6 | ...... | |
| Barley (*Hordeum vulgare*) 1. | in the same | 10 | 29·0 | 28·7 | 42·5 | 4th year, 1838 | 21·5 | 3rd year, 1837 | 30·0 | 28·9 | 36·4 | Dried in the sun before weighing. |
| 2. | in different | 10 | 35·5 | 30·5 | 75·0 | 4th year, 1838, after Endive | 27·4 | 7th year, 1841, after Beans | 46·5 | 42·1 | ...... | |
| Turnips (*Brassica Rapa*) 1. | in the same | 10 | 185·0 | 77·0 | 185·0 | 1st year, 1835 | 37·2 | 3rd year, 1837 | 104·0 | 100·8 | 140·0 | In a green state when weighed. |
| 2. | in different | 10 | 192 0 | 148·0 | 245·0 | 7th year, 1841, after Poppies | 110·0 | 9th year, 1843, after Potatoes | 173·0 | 176·5 | ...... | |
| Hemp (*Cannabis sativa*) 1. | in the same | 9 | 46·5 | 21·5 | 46·5 | 1st year, 1836 | 20·5 | 5th year, 1840 | 32·55 | 30·13 | 42·0 | Dried in the sun before weighing. |
| 2. | in different | 7 | 52·5 | 37·6 | 53·0 | 7th year, 1842, after Beet | 22·5 | 2nd year, 1837, after Turnips | ...... | 40·0 | ...... | |
| Spurge (*Euphorbia lathyris*) 1. | in the same | 3 | 17·2 | 0· | ...... | ...... | ...... | ...... | ...... | ...... | ...... | Dried before weighing. |
| Poppy (*Papaver somniferum*) 1. | in the same | 9 | 38·0 | 8·65 | 38·0 | 1st year, 1836 | 8·65 | 9th year, 1844 | 21·9 | 18·2 | ...... | Dried in the sun before weighing. |
| 2. | in different | 9 | 27·0 | 13·5 | 27·0 | 1st year, 1836, after Spurge | 11·0 | 3rd year, 1837, after Endive | 20·3 | 18·7 | ...... | |
| Clover (*Trifolium pratense*) 1. | in the same | 10 | 8·5 | 7·6 | 30·0 | 7th year, 1840 | 7·5 | 11th year, 1844 | 10·9 | 14·8 | ...... | Dried in the sun before weighing. |
| 2. | in different | 6 | 11·3 | 31·0 | 31·0 | 6th year, 1840, after Spurge | 11·3 | 1st year, 1835, after Larkspur | ...... | 16·9 | ...... | |
| Endive (*Cichorium endivia*) 1. | in the same | 10 | 68·5 | 72·0 | 72·0 | 1st year, 1834 | 22·0 | 7th year, 1840 | 53·9 | 51·5 | ...... | Dried in the sun before weighing. |
| 2. | in different | 5 | 68·0 | 38·0 | 68·0 | 2nd year, 1835, after Buckwheat | 34·0 | 4th year, 1837, after Barley | ...... | 47·0 | ...... | |
| Mint (*Mentha viridis*) 1. | in the same | 10 | 21·9 | 16·5 | 53·0 | 2nd year, 1836 | 12·0 | 9th year, 1843 | 31·5 | 24·7 | ...... | Dried in the sun before weighing. |
| 2. | in different | 4 | 17·0 | 36·8 | 36·8 | 4th year, 1838 | 9·25 | 3rd year, 1837 | ...... | 22·5 | ...... | |
| Buckwheat (*Polygonum fagopyrum*) 1. | in the same | 10 | 12·8 | 5·1 | 16·0 | 4th year, 1838 | 3·2 | 7th year, 1841 | 11·6 | 9·1 | ...... | Dried in the sun before weighing. |
| 2. | in different | 10 | 14·8 | 6·6 | 18·0 | 4th year, 1838, after Poppies | 5·5 | 3rd year, 1837, after Valerian | 12·5 | 10·6 | ...... | |
| Parsley (*Petroselinum sativum*) 1. | in the same | 10 | 68·25 | 33·0 | 115·0 | 2nd year, 1836 | 9·4 | 8th year, 1842 | 61·25 | 39·75 | ...... | In a green state when weighed. |
| 2. | in different | 6 | 74·0 | 83·0 | 208·0 | 2nd year, 1836, after Beans | 32·5 | 5th year, 1839, after Mint | ...... | 87·8 | ...... | |
| Tobacco (*Nicotiana rustica*) 1. | in the same | 10 | 172·0 | 37·8 | 172·0 | 1st year, 1834 | 17·25 | 6th year, 1839 | 69·2 | 48·0 | ...... | Dried in the sun before weighing. |
| 2. | in different | 8 | 42·0 | 49·0 | 49·0 | 10th year, 1844, after Turnips | 22·5 | 6th year, 1839, after Flax | ...... | 32·0* | ...... | |
| Oats (*Avena sativa*) 1. | in the same | 6 | 31·0 | 14·6 | 44·0 | 2nd year, 1840 | 14·6 | 6th year, 1844 | ...... | 28·0 | ...... | Dried in the sun before weighing. |
| 2. | in different | 6 | 37·5 | 14·7 | 53·0 | 2nd year, 1840, after Clover | 14·7 | 5th year, 1843, after Sunflower | ...... | 32·4 | ...... | |
| Beet (*Beta vulgaris*) 1. | in the same | 6 | 312·0 | 135·0 | 344·0 | 4th year, 1842 | 135·0 | 5th year, 1843 | ...... | 256·0 | ...... | In a green state when weighed. |
| 2. | in different | 5 | 330·0 | 200·0 | 330·0 | 1st year, 1840, after Hemp | 173·0 | 3rd year, 1842, after Oats | ...... | 231·0 | ...... | |
| Tares (*Vicia sativa*) 1. | in different | 4 | 14·0 | 10·0 | 20·0 | 4th year, 1842 | 9·0 | 5th year, 1843 | ...... | 13·25 | ...... | Dried in the sun before weighing. |
| Sunflower (*Helianthus annuus*) 1. | in different | 4 | 40·0 | 165·0 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | Dried in the sun before weighing. |

* The average is here lower than in the former, because two crops of a different kind had been previously taken off the ground before the first crop of Tobacco was sown. Hence this is so much inferior to the first crop of the preceding column.

It appears then that out of the whole series, there are only four cases in which the average amount of the permanent crop was equal or superior to that of the shifting one.

In the first of these, the Tobacco, the fact may be accounted for, from the condition of the ground being more favourable to the permanent than to the shifting crop on the year of its introduction, the former being obtained from soil which had been recently manured, the latter from what had been partially exhausted by preceding crops.

The second, the Beet, was scarcely continued for a sufficient length of time to lead to any certain conclusions.

The two others, namely, the Endive and Mint, present results so nearly agreeing in the amount of their permanent and shifting crops, that the slight disparity may be fairly referred to contingent circumstances, and an uniformity in the products obtained may in consequence be inferred.

Setting aside then the above four cases as exceptional, the general tenor of the experiments would seem to indicate a *manifest* advantage on the side of the shifting crops, varying from 1 to 75 per cent., but more generally approaching to the latter.

Yet it by no means follows that this difference is to be attributed to the influence of root excretions. Were such the cause, we ought to perceive a more regular, as well as a more rapid, diminution in the permanent crop than is indicated in these Tables; we should not find, for instance, the crop of potatoes equalling in the fifth year the produce of the first; the Turnips, after sinking to 37·0 lbs. in the third year, rising in the sixth to 128 lbs.; not to allude to other similar instances of oscillation.

If De Candolle's theory too could be carried out, we might have expected to find a more manifest improvement in the shifting crop occasionally occurring, owing to the excretions of the family of plants which had preceded it proving congenial to its constitution.

But if nothing positively injurious be imparted to the soil by the crop, the gradual falling off in the amount of the latter can only be attributed to the deficiency, either of organic, or of inorganic matter fitted for its development, in the soil in which it was reared.

Of the two continental writers on chemical agriculture whose works have excited the greatest interest in this country, the one would seem to favour the former, the other the latter explanation, although it may be more correct to consider them, as viewing the subject under two different aspects, rather than as laying down principles irreconcileable one with the other.

Liebig, for instance, although he regards the presence of certain inorganic matters as the only condition *essential* to the existence of a plant, does not deny, that its growth may be accelerated in proportion to the ready access to it of ammonia and carbonic acid, and these, it is evident, would be supplied more abundantly by the presence in the soil of organic matter in a readily decomposable condition.

Nor, on the other hand, would Boussingault deny the necessity for a supply of the inorganic principles, which form, as it were, the skeleton of each plant, although he attributes the peculiar benefit derived from fallow crops to their power of generating the organic matter which is required by the cereals that are to succeed them.

In order to determine then in what degree the falling off of the permanent crop arose from the one or the other of these causes, it seemed necessary to obtain an analysis of the plants derived from this and from the shifting crop corresponding, and to compare the composition of both with that of a standard specimen of the same plant determined by the method pursued with respect to the two former; and it would have been also satisfactory, not only to ascertain, whether the soil itself originally contained such a store of all the principles existing in the crop, as might be sufficient to meet the demand made upon it for that purpose during the whole decennial period, but also whether its present composition was such, as actually indicated a deficiency in any of the principles which entered into the constitution of the plants grown in it.

It is evident that the former branch of the inquiry would have been superfluous, if I could have depended on two things:—

1st. That the analyses given by Sprengel and others, of the plants to which the inquiry related, were trustworthy; and

2ndly. That the composition of the same vegetable was at all times uniform both as to the quality and quantity of its ingredients.

But with respect to the former point, I found, on turning to the analyses given of the ashes of the same plants by different authorities, many marked discrepancies, and that those of Sprengel, which are the most numerous of any we could appeal to, were regarded as inaccurate by other chemists of higher distinction.

Nor, even if they had represented truly the composition of the plants which were actually examined by that analyst, could we be sure, that they would apply to those of the same species, grown in a different country, and under altered circumstances, more particularly as the recent researches of Liebig, Will, Fresenius and others, appeared to indicate, that certain ingredients admit of being substituted for others, according to laws as yet not fully made out.

For all these reasons then, it became necessary for my purpose to obtain a correct analysis, both of the crops, and of the soil; and I was the more reconciled to the expenditure of labour involved in this undertaking, when I reflected, that the results obtained were likely not only to lead to an explanation of the cause of the utility of a rotation of crops, but also to throw some incidental light upon certain other points connected with the chemistry of agriculture, which did not appear to be sufficiently elucidated; such for instance, as the degree of variation of which a plant may admit in the quality and quantity of its inorganic ingredients, or in other words, its power of substituting one principle for another, and likewise as to the state of combination, in which the alkalies, phosphates, &c. exist with the other constituents of the soil, when in a condition to be assimilated by a plant.

I shall, therefore, next proceed to state the results of the analyses of the several crops which were made in my laboratory by Mr. **Way**.

## PART II.

*On the chemical composition of certain crops cultivated in the Botanic Garden, and on the amount of inorganic principles abstracted by them from the soil during the period the experiments were continued.*

It is only within a few years that the importance of ash analyses has been understood, and we were consequently much at a loss for accurate instructions as to the best method of conducting it.

A valuable paper has however recently appeared in the Memoirs of the Chemical Society of London (Part IX.), by **Will** and **Fresenius**, which in a great degree supplies this deficiency, and which we therefore determined to adopt as the basis of our scheme of operations.

One part of it, however, relating to the determination of the phosphoric acid, was soon found extremely troublesome in practice, and too tedious to be resorted to in an inquiry which involved the necessity of so large a number of analyses. In this part therefore of the process, Mr. **Way** suggested a method, which, as it recommended itself from its greater simplicity, and appeared to answer well in practice, he has adopted in all the cases, of which mention will hereafter be made.

But although the plan of analysis pursued presents in other respects but little of novelty, yet as certain modifications of the scheme of the German chemists have been here and there introduced, and as some of the manipulations may admit of being more clearly explained than in the paper alluded to, it will not be amiss to set down, as briefly as possible, all the principal steps pursued for the determination of the several ingredients existing in the ash.

In a few instances, as in the Cerealia, where the ashes abounded in silicates, complete solution in acids could not be effected, until the whole had undergone, either a previous fusion with carbonate of barytes, or evaporation with caustic potass, the former substance being employed for that portion of the ash which was to be examined for alkalies, the latter for the one set apart to ascertain the other ingredients.

But where the whole of the ash proved soluble in muriatic acid, no such preliminary process was required, and we were able to proceed directly to dissolve it in this menstruum.

A certain amount, however, of sand derived from the soil in which they had grown, and of charcoal, from the organic matter of the plant which had not been burnt off, was always present, and these of course would not be acted upon by this acid.

There was also in every instance a variable quantity of peroxide of iron proceeding manifestly from the vessels in which the combustion had been carried on, the quantity to be burnt being too considerable to allow of its calcination in any of the platina vessels which I chanced to possess.

The ashes, therefore, of which 200 grains were usually taken, had first to be treated with pure muriatic acid, and the latter to be driven off by heat, so that the silica of the ash might be rendered insoluble.

Water and muriatic acid were then added to the dry mass, and the portion which did not dissolve was separated by filtration. Its weight, after being washed, represented the amount of silica in the ash, together with that of the extraneous sand and charcoal intermixed with it. The former was separated by digestion in pure dilute alkaline ley, and its quantity determined, in the first place indirectly, by the loss of weight sustained by the insoluble portion after its removal, and in the second more accurately, by the direct process of separating it from its solution in the alkali by treatment with an acid, and subsequent evaporation to dryness, after which, water having been added in sufficient quantity to redissolve the alkaline salt, the silica was collected on a filter, and then dried and ignited previously to weighing it.

The solution in dilute muriatic acid was made up to some definite quantity, so that it might be divided into four exactly equal portions, of which one was kept in reserve in case of any accident happening to the remainder, whilst the three others, which we will call A, B and C, were examined for the different ingredients present, as for instance,—

A. For the peroxide of iron.
B. For the phosphoric acid.
C. For the alkalies.

In most of the parts of vegetables, especially in their seeds, and in the tubers and bulbs which afford nutriment to animals, the amount of phosphoric acid may be expected to exceed that necessary for combining with the iron present. A reagent then which throws down phosphate of iron, affords us in these cases a ready means of estimating the whole amount of that metal, from the weight of phosphate obtained, and Will assures us[*] that 100 grains of the latter precipitate consists of 43·92 phosphoric acid, and 56·08 peroxide of iron.

When therefore, to the muriatic solution A, containing a slight excess of acid, acetate of ammonia is added, the muriatic acid, which had held the phosphate of iron in solution, is seized upon by the ammonia of the former salt, and the phosphate of iron, being insoluble in the liberated acetic acid, is precipitated.

We thus obtain a means of readily estimating the amount of peroxide of iron, but not of determining that of phosphoric acid, because there may be still a portion of the latter remaining in the liquid in combination with other bases, the phosphate of lime and of magnesia being soluble in free acetic acid, and the alkaline phosphates being so even in water.

In order therefore to estimate the amount of phosphoric acid, an expedient was adopted, by which the presence of sufficient iron to carry down the whole of the phosphoric acid might be secured.

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[*] Memoirs of the Chemical Society, part 9.

For this purpose a certain known weight of clean iron wire was dissolved in a mixture of nitric and muriatic acids, care being taken that no loss should occur from the violence of the action occasioned.

The solution thus prepared will then contain a definite amount of peroxide of iron, which, when introduced into the liquid containing the ash, will seize upon all the phosphoric acid, not already combined with iron, which it may contain.

Accordingly, after adding it to the latter, from which the phosphate of iron originally present had been previously thrown down by acetate of ammonia, we recover the whole of the metal, whether in combination with phosphoric acid or not, by applying again this same reagent, provided only the solution be rendered neutral by ammonia, and raised to a boiling temperature.

In the case supposed, therefore, the precipitate will indicate the whole of the phosphoric acid existing in the fluid, after the phosphate of iron originally present had been thrown down, together with the peroxide of iron which results from the iron introduced into it in union with chlorine.

Accordingly the quantity of phosphoric acid remaining after the first operation may be estimated, by deducting the weight of peroxide of iron, which is known, from that of the entire precipitate collected.

In practice however it was found most convenient to determine the amount of phosphoric acid, by taking another measured portion of the solution, viz. B, and adding to it in the first instance the known weight of iron. We are thus enabled, by following the steps above pointed out, to throw down, all the iron originally present in combination with phosphoric acid, all the phosphoric acid which may have existed in combination with other bases, and the whole of the peroxide of iron, whether proceeding from the ash, or introduced from without.

The amount of the former portion of the iron will have been ascertained by the examination of the solution A, whilst that of the latter can be readily calculated, as we know the weight of the iron introduced; by deducting therefore the sum of these two, which represents the total amount of peroxide of iron, from the entire weight of the precipitate, we obtain that of the phosphoric acid present in the ash.

This modification of the process saves some trouble, as it obviates the necessity of reducing the bulk of the solution remaining after the separation of the phosphate of iron precipitated from A. in the first process, which, owing to the number of washings necessary, becomes inconveniently large.

I felt curious to ascertain whether the phosphoric acid obtained by the above method was combined with two or with three atoms of base, as Will and Fresenius state, that the Cerealia generally present it in the former predicament, the Leguminosæ in the latter.

Our experiments on this point do not appear to confirm such a conclusion, showing rather, that the proportion of base to acid has some reference to the quantity of alkali present, and is therefore dependent in a certain degree upon the manner in which the previous calcination had been conducted.

Supposing a plant to be rich in alkali, and to contain but little silex, it would seem natural to expect, that the phosphoric acid would be united with three atoms of bases.

When, on the contrary, the proportion of silica was large, a strong heat would cause more of it to unite with the alkali, and hence there might be only enough of the latter remaining to form a bibasic combination with phosphoric acid. Yet even here, if a slighter heat had been applied, it might happen that a tribasic compound would be produced.

Thus we found, that in all the three crops of potatoes the phosphate gave a yellow precipitate with nitrate of silver, and the same was also the case in the turnips; but in only one sample of beans, viz. the shifting crop, and in one of barley, which was also the shifting one, did the same hold good.

On the other hand, in two other samples of ash from the barley, and in two samples of that from the beans, the phosphoric acid seemed, from the precipitate afforded by nitrate of silver, to be united with two atoms only of base.

It is easy to determine the amount of lime and of magnesia from either of the liquids already operated upon, oxalate of ammonia being added to separate the former, and, after neutralizing with ammonia the acid solution, phosphate of soda throwing down the magnesia.

In these respects the common methods were adhered to.

The solution C. was reserved for the determination of the alkalies.

For this purpose it is necessary to get rid of all the earths and metallic oxides which may be present, which is accomplished by adding barytic water so long as a precipitation takes place. That reagent of course throws down the whole of the sulphuric and phosphoric acids, the peroxide of iron, most of the magnesia, and most of the lime*.

The filtered solution may however contain a little magnesia and lime, and probably much barytes.

To remove these, carbonate of ammonia is added in excess, and the precipitate which is thrown down removed by filtration, after being allowed to stand until it becomes heavy and granular.

If this be duly performed, the remaining solution can contain only muriate of ammonia and chlorides of the fixed alkalies.

The former is removed by heat, and the dry chlorides then remaining will represent the weight of the alkaline salts originally present in the ash. Having ascertained this, the dry residue is dissolved in a small quantity of water, chloride of platinum added, and the whole evaporated nearly to dryness. It is then treated with dilute alcohol, which takes up the double chloride of platinum and sodium*, together with any excess of the reagent that may have been added. The undissolved residue is the double chloride of platina and potass, from which the amount of the chloride of potassium may be calculated. The difference between the weight of the latter and of the whole salt gives that of the chloride of sodium proceeding from the ash.

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* As the entire precipitate, excepting what consists of sulphate of barytes, is soluble in muriatic acid, we may estimate the amount of sulphuric acid present, by treating it with the former acid, removing all that is soluble in water by filtration, and lastly weighing the dried residue, from which the weight of sulphuric acid may be readily deduced.

The carbonic acid present was best ascertained by operating on a separate portion of the ash, and the common method of determining it by the loss of weight consequent upon the addition of a stronger acid was adopted, with the precautions usually taken†.

The chlorine also was determined in the usual manner by nitrate of silver, a separate portion of the ash being employed for that purpose.

In the analyses given, it has been usual to consider it as in combination either with sodium or with potassium. That this was the case, seemed probable from the curious relation generally found to subsist between the quantity of chlorine and of sodium detected, which in many instances approximated so nearly, that we were led to conclude, that the chlorine in these instances merely implied a corresponding amount of chloride of sodium existing in the ash. That the correspondence should not have been exact, may be more readily explained, when we consider that the only generally practicable mode of estimating soda is an indirect one, and therefore liable to some degree of uncertainty.

In the few instances where the amount of chlorine was more than proportionate to that of the sodium, it was thought consistent with analogy to regard that portion of the former which was in excess, as held in combination with the vegetable alkali, or as representing an equivalent weight of chloride of potassium.

This mode of stating the results may appear objectionable, as blending theory with fact, but my reason for adopting it is, that it points at an important general conclusion, which it is hoped future inquiries will either negative or confirm, namely that the base of the soda found in plants commonly enters them in a state of combination with chlorine, being derived from the common salt, taken up, but not decomposed, by the organs of the plant.

Such an inference indeed cannot be adopted by those who receive the analyses given by **Sprengel** as correct, for in many of these large quantities of soda are stated as having been detected; but, without presuming to bring forward the analyses made in my laboratory as in themselves sufficient to justify the public in rejecting the former as inaccurate, I may be permitted to observe, that it is much more easy to conceive that the amount of soda present may have been *overrated*, than that it should have been estimated *below* its real amount, supposing anything like an equality of skill and attention on the part of the operator.

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* This double chloride is readily decomposed, if first rubbed up with mercury, which flies off along with the chlorine in the form of calomel, when heated.

† It seems a defect in the analyses reported by **Sprengel**, that this ingredient is never mentioned in them; for although it may not be present as such in the crop, yet its amount in the ash probably represents that of the organic acids existing in the plant previously to its being burnt, and hence the proportion which it bears in different samples of the same species to the phosphoric and other mineral acids, may tend to indicate the relation subsisting between the amount of organic and of inorganic matter, arising from the mode of culture or other circumstances.

To overrate it, we need only attribute to him some degree of negligence, either in not converting by means of chloride of platinum the whole amount of chloride of potassium into the sparingly soluble double chloride, or in not determining its entire quantity; to estimate it too low, we must imagine, what is far less probable, a portion of the readily soluble compound of chlorine with sodium, or the equally soluble double salt which the latter forms with platinum, to remain attached to the chloride of potassium and platinum, and thus to add to its weight.

Our results may also appear to militate against the conclusions of a much higher authority than SPRENGEL, I mean Professor LIEBIG, who has lately represented that one alkali may be substituted for another in the organization of a plant, and that a species, which in inland spots assimilates a certain amount of potass, takes into its frame an equivalent proportion of soda in maritime districts, where the latter alkali abounds.

With the slender data before me, it would be the height of presumption to impugn the generalisations of this distinguished philosopher, but it will be seen from the analyses given below, that no difference in the nature of the alkaline ingredients could be detected between barley, taken from the neighbourhood of the sea, whether from the eastern or western coasts of this country, and from the more central region of Oxfordshire.

Two ingredients mentioned by SPRENGEL as existing in the ashes of plants were searched for in a few of those to which this paper refers, but without success. These were alumina and manganese, the former so universally present in the soil, that it may readily find admission into the ashes of the plants, unless the greatest care be taken to clean off every particle of dirt entangled by their roots; the latter, as LIEBIG thinks, an accidental ingredient, being taken up by many plants in considerable quantities where the soil contains much of it, but altogether wanting in the same vegetables cultivated elsewhere.

In order to ascertain the presence of alumina, the ash was dissolved in muriatic acid, the solution evaporated to dryness, in order to separate the silica, and then redissolved in muriatic acid diluted with water.

An excess of ammonia was afterwards added to the filtered liquor, and the precipitate which fell, after having been well-washed, was boiled with a pure solution of potass. The portion dissolved was then filtered, neutralized with muriatic acid, and treated a second time with ammonia. If any precipitate had been thrown down, the presumption would have been that it consisted of alumina, and the appropriate tests would have been applied to confirm the conjecture; but in the only instance in which we could positively assure ourselves that no admixture of the soil had got in, namely, in the grain of barley from Ensham, nothing was thrown down by the last application of ammonia, and in one sample of ash from flax (viz. the standard crop), only a mere trace was discoverable.

Considering indeed that the soluble salts of alumina are poisonous to plants, and that the earth itself is confessedly present in very variable, sometimes very minute, quantities, I am inclined to doubt whether it be in reality a constituent of their ashes at all.

With respect to manganese, two methods were adopted for ascertaining its presence.

The first, that of boiling the muriatic solution with carbonate of lime, and then, after filtering it, adding hydrosulphuret of ammonia.

The second, the blow-pipe test, fusing a little of the muriatic salt with borax, when a very minute quantity of manganese would produce its characteristic colour in the bead of glass produced.

By neither of these methods were any indications of manganese obtained.

I next proceed to state the results of the analyses made in my laboratory by Mr. Way, of six kinds of crops grown in the experimental garden, together with those obtained from certain standard crops of the same species, grown in another part of the garden, or in other places in the vicinity of Oxford, under more natural circumstances.

My original object being merely that of ascertaining the quality and quantity of the inorganic matters abstracted from the soil in these instances, the crop of barley, flax, hemp and beans, was burnt altogether without any separation of their respective parts having been previously made, and it was only in the case of the potatoes and the turnips that a distinct portion of the plant was selected for analysis, namely, the tubers in the former, and the bulbs in the latter.

### Barley.

Permanent crop, after ten years' repetition.

100 grains of the dried crop, including both the straw and grain, left of ash 8·7 grains.

100 grains of this ash contained as follows:—

| | |
|---|---|
| Sand and charcoal, extraneous | 22·36 |
| Peroxide of iron, chiefly extraneous | 2·12 |
| | 24·48 |
| Silica of the plant | 24·60 |
| Phosphoric acid | 7·31 |
| Sulphuric acid | 2·12 |
| Carbonic acid | 1·94 |
| Chloride of sodium | 4·73 |
| Potass | 17·33 |
| Magnesia | 4·68 |
| Lime | 13·91 |
| Total | 101·14 |

### BARLEY.

Grown in the same part of the garden as the last, for ten years unmanured, distinguished as the *shifting crop*.

100 grains of the dried crop, including as before both the straw and the grain, left of ash 6·25 grains.

100 grains of this ash contained as follows:—

| | |
|---|---|
| Sand and charcoal, extraneous | 21·91 |
| Peroxide of iron, chiefly extraneous | 2·30 |
| | 24·21 |
| Silica of the plant | 36·47 |
| Phosphoric acid | 9·30 |
| Sulphuric acid | 2·35 |
| Carbonic acid | 1·44 |
| Chloride of sodium | 1·43 |
| Potass | 16·58 |
| Magnesia | 3·58 |
| Lime | 7·72 |
| | 103·08 |

### BARLEY.

Grown in a distinct part of the garden. Soil similar, but recently manured, distinguished as the *standard crop*.

100 grains of the dried crop, including as before the straw and grain, gave of ash 7·15 grains.

100 grains of this ash contained as follows:—

| | |
|---|---|
| Sand and charcoal, extraneous | 16·60 |
| Peroxide of iron, chiefly extraneous | 2·30 |
| | 18·90 |
| Silica of the plant | 37·27 |
| Phosphoric acid | 7·67 |
| Sulphuric acid | 4·37 |
| Carbonic acid | 1·51 |
| Chloride of sodium | 1·84 |
| Potass | 13·86 |
| Magnesia | 3·96 |
| Lime | 11·81 |
| | 101·19 |

It would appear then from the above analyses, that the principal difference between the permanent crop and the two others consisted in the larger amount of soluble silica, which, together with the greater proportion of ash, may have arisen from the straw predominating in quantity over the grain.

It next appeared to me desirable, both by way of testing the accuracy of these results, and likewise of ascertaining whether the third sample of barley analysed might really be adopted as a fair representative of a standard crop, to examine separately the grain and straw taken from a crop of average quality grown in the neighbourhood of Oxford.

Mr. Druce of Ensham accordingly supplied me with a sample of barley from his farm, of which the following analysis was made by Mr. Way.

1000 parts of the crop of barley from a field near Ensham, situated on the Oxford clay, consisted of—

| | |
|---|---|
| Grain . . . . . . | 575 |
| Aulm . . . . . . | 37 |
| Straw . . . . . . | 388 |
| | 1000 |

*Of the Grain.*—100 parts yielded of ash 2·04 parts, 100 grains of which consisted of—

| | |
|---|---|
| Charcoal*, extraneous . | 24·51 |
| Peroxide of iron, extraneous | 2·30 |
| | 26·81 |
| Ingredients of the grain . | 73·86, viz.— |
| Total . . . | 100·69 |

| | | | Excluding extraneous matter. |
|---|---|---|---|
| Silica . . . . . | 24·51 | or | 33·2 |
| Phosphoric acid . | 22·97 | or | 31·2 |
| Sulphuric acid . . | 2·48 | or | 3·4 |
| Carbonic acid . . | | | |
| Chloride of sodium | 1·48 | or | 2·3 |
| Potass . . . . | 14·10 | or | 19·1 |
| Magnesia . . . | 5·63 | or | 7·6 |
| Lime . . . . . | 2·71 | or | 3·6 |
| | 73·86 | | 100·4 |

*Of the Straw.*—100 parts yielded 4·2 of ash, of which 100 parts contained—

| | |
|---|---|
| Sand and charcoal, extraneous | 4·20 |
| Peroxide of iron, extraneous . | 4·74 |
| | 8·94 |
| Ingredients of the straw. . | 94·62, viz.— |
| Total . . . . | 103·56 |

| | | | Excluding extraneous matter. |
|---|---|---|---|
| Silica . . . . | 44·72 | or | 47·20 |
| Phosphoric acid . | 1·68 | or | 1·80 |
| Sulphuric acid . | 4·38 | or | 4·60 |
| Carbonic acid . | 1·21 | or | 1·27 |
| Chloride of sodium | 7·85 | or | 8·25 |
| Soda . . . . | 0·98 | or | 1·06 |
| Potass . . . . | 22·98 | or | 24·40 |
| Magnesia . . . | 1·67 | or | 1·70 |
| Lime . . . . | 9·15 | or | 9·65 |
| | 103·56 | | 99·93 |

---

* In this instance the extraneous matter not dissolved by muriatic acid proved to consist almost wholly of

***Of the Aulm.***—100 parts yielded 13·7 of ash, of which 100 parts contained—

Charcoal and sand, extraneous 6·22
Peroxide of iron, extraneous 1·53

7·75

Ingredients of the aulm . . 90·58, viz.—

Total . . . . . . 98·33

| | | | Excluding extraneous matter. |
|---|---|---|---|
| Silica . . . . | 80·96 | or | 89·50 |
| Phosphoric acid . | 1·20 | or | 1·30 |
| Sulphuric acid . | 0·89 | or | 0·90 |
| Carbonic acid . | a trace | | 0·00 |
| Chloride of sodium | 0·73 | or | 0·80 |
| Soda . . . . | 0·22 | or | 0·24 |
| Potass . . . . | 1·23 | or | 1·30 |
| Magnesia . . . | 0·90 | or | 0·99 |
| Lime . . . . | 4·50 | or | 5·00 |
| | 98·33 | | 100·03 |

According to these data the crop of barley will consist as follows :—

| | Parts. | | Parts. | | Parts. | Total. |
|---|---|---|---|---|---|---|
| Grain . . . . . | 57500 | Straw . . . . . | 38800 | Aulm . . . . . | 568 | 96868. |
| Yielding of ash . | 1170 | Yielding of ash . | 1629 | Yielding of ash . | 77·5 | 3406·5 |
| Of which the extraneous matter amounted to | 313 | Of which the extraneous matter amounted to | 141 | Of which the extraneous matter amounted to | 5·5 | 459·5 |
| Real ash . . | 857 | Real ash . . | 1488 | Real ash. . | 72·0 | 2417·0 |
| The latter consisting of | | Consisting of | | Consisting of | | |
| Silica . . . . . | 287 | Silica . . . . . . | 705 | Silica . . . . . | 64·50 | 1056·50 |
| Phosphoric acid . | 270 | Phosphoric acid . | 26 | Phosphoric acid . | 0·13 | 296·13 |
| Sulphuric acid . . | 29 | Sulphuric acid . . | 70 | Sulphuric acid . | 0·65 | 99·65 |
| Carbonic acid . . | 00 | Carbonic acid . . | 18 | Carbonic acid . | 0·00 | 18·00 |
| Chloride of sodium | 17 | Chloride of sodium | 122 | Chloride of sodium | 0·57 | 139·57 |
| Soda . . . . . . | 00 | Soda . . . . . . | 15 | Soda . . . . . | 0·14 | 15·14 |
| Potass . . . . . | 164 | Potass . . . . . | 361 | Potass . . . . . | 0·93 | 525·93 |
| Magnesia . . . . | 65 | Magnesia . . . | 25 | Magnesia . . . | 0·65 | 90·65 |
| Lime . . . . . . | 31 | Lime . . . . . . | 143 | Lime . . . . . | 3·60 | 177·60 |
| | 863 | | 1485 | | 71·17 | 2419·17 |

Now according to this calculation, 100 parts of the mixed ash ought to contain the subjoined quantities of the ingredients below-mentioned, and by comparing these with the composition given of the ashes obtained from the three crops grown in the Botanic Garden, which I have deduced from the analysis before given, after deducting in each instance the matters regarded as extraneous, it will be seen that there is a near correspondence.

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charcoal, for after the first analysis had been completed, another portion of the ash was fused with potass, after which the silica obtained agreed within 0·2 with that procured in the first instance by the usual process.

I am the more anxious to state this, as it will be seen from the statement given in a subsequent page, that there is a great discrepancy between the per-centage of silica given in Mr. WAY's analysis and that reported by SPRENGEL, a discrepancy which, without this explanation, might be attributed to a want of care on his part in not dissolving the whole of the silica.

**100 grains of real ash contain,—**

| Druce's Barley and Barley-straw. | | Botanic Garden. | | |
|---|---|---|---|---|
| | | Permanent. | Shifting. | Standard. |
| Silica . . . . . . . . | 43·6 | 32·3 | 46·1 | 45·0 |
| Phosphoric acid . . . . | 12·2 | 9·5 | 11·8 | 9·2 |
| Sulphuric acid . . . . | 4·1 | 2·7 | 2·9 | 5·2 |
| Carbonic acid . . . . | 0·7 | 2·5 | 1·7 | 1·8 |
| Chloride of sodium . . . | 5·7 | 6·1 | 1·7 | 2·1 |
| Soda . . . . . . . . | 0·6 | 0·0 | 0·0 | 0·0 |
| Potass . . . . . . . | 21·7 | 22·6 | 20·9 | 16·8 |
| Magnesia . . . . . . | 3·7 | 6·0 | 4·4 | 4·7 |
| Lime . . . . . . . | 7·3 | 18·2 | 9·7 | 14·3 |
| Total . . . . | 99·6 | 99·9 | 99·2 | 99·1 |
| Or Acids . . . . . | 17·00 | 14·7 | 16·4 | 16·2 |
| Bases . . . . . | 32·70 | 46·8 | 35·0 | 35·8 |

These results are interesting on two accounts; first, as they show what the composition of barley is when cultivated under natural circumstances, or within what limits its variation from a normal condition may be circumscribed; secondly, as they confirm the general exactness of the preceding analyses, by the correspondence which is seen to exist between the composition of the shifting crop, as ascertained by experiment, and that of the sample obtained from Mr. Druce's brought out by the above method of computation.

As the analyses of the ash, both in the case of the straw and of the grain, were performed by Mr. Way, whilst the proportion between the grain and straw, as well as that subsisting in each instance between the crop and its ash, was ascertained by myself, the statement which I have just submitted as to the real composition of the crop, calculated from these data, would hardly have presented so near an accordance with the analysis made of the entire crop which I had obtained in the Botanic Garden, had not both the one and the other been executed with considerable care.

It was far otherwise, however, when we compared our results with those of Sprengel, in which, amongst other striking discrepancies, we observe, that the proportion of soda stated to exist in the grain exceeds that of the potass, whilst in our analyses, only so much as was equivalent to the amount of chlorine appeared to be present*.

| * Our analysis of *Hordeum vulgare*. | | Sprengel's, of *Hordeum distichum*. | | Bichon's, as quoted by Will. | |
|---|---|---|---|---|---|
| Silica . . . . . . . . . . . . . . . . | 33·2 | Silica . . . . . . . . . . . . . . . . | 50·2 | Silica . . . . . . . . . . . . . . . . | 21·99 |
| Phosphoric acid . . . . . . . . | 31·2 | Phosphoric acid . . . . . . . . | 8·4 | Phosphoric acid . . . . . . | 40·68 |
| Sulphuric acid . . . . . . . . . . | 3·4 | Sulphuric acid . . . . . . . . | 2·5 | Sulphuric acid . . . . . . . . | 0·26 |
| Carbonic acid . . . . . . . . . . | 0·0 | Carbonic acid . . . . . . . . . . | 0·0 | Carbonic acid . . . . . . . . | 0·00 |
| Chloride of sodium . . . . . . | 2·3 | Chloride of sodium . . . . | 0·0 | Chloride of sodium . . . . | 0·00 |
| Potass . . . . . . . . . . . . . . . . | 19·1 | Potass . . . . . . . . . . . . . . . . | 11·80 | Potass . . . . . . . . . . . . . . | 3·91 |
| Soda . . . . . . . . . . . . . . . . | 0·0 | Soda . . . . . . . . . . . . . . . . | 12·30 | Soda . . . . . . . . . . . . . . . . | 16·79 |
| Magnesia . . . . . . . . . . . . . . | 7·6 | Magnesia . . . . . . . . . . . . | 7·65 | Magnesia . . . . . . . . . . . . . . | 10·05 |
| Lime . . . . . . . . . . . . . . . . | 3·6 | Lime . . . . . . . . . . . . . . . . | 4·50 | Lime . . . . . . . . . . . . . . . . | 3·36 |
| Alumina . . . . . . . . . . . . . . | 0·0 | Alumina . . . . . . . . . . . . . . | 1·50 | Alumina . . . . . . . . . . . . | 0·00 |
| | 100·4 | | 99·95 | | 97·03 |

This discrepancy made me desirous of learning, whether, in accordance with the observations of Will and Fresenius, any marked variation in the character of the alkaline constituent might subsist between barley cultivated in an inland county like Oxfordshire, and near the sea, and I therefore procured, through the kindness of a friend, one sample from the coast of Essex, and another from that of Cardiganshire, in South Wales.

The following were the results obtained of barley from the sea coast of Essex:—

1000 grains yielded 19 grains of ash.

100 grains of this ash contains, of—

| | | |
|---|---|---|
| Sand and charcoal, extraneous | 23·28 | |
| Peroxide of iron, extraneous | 2·44 | |
| | 25·72 | |
| Silica | 24·89, or, excluding extraneous matter | 34·0 |
| Phosphoric acid | 21·84, or, excluding extraneous matter | 29·7 |
| Sulphuric acid | 1·79, or, excluding extraneous matter | 2·4 |
| Carbonic acid | 0·00 | 0·0 |
| Chloride of sodium | 0·00, there being no chlorine in the ash. | |
| Soda | 1·05, or, excluding extraneous matter | 1·3 |
| Potass | 15·42, or, excluding extraneous matter | 21·1 |
| Magnesia | 5·29, or, excluding extraneous matter | 7·2 |
| Lime | 3·36, or, excluding extraneous matter | 4·5 |
| | 99·36 | 100·2 |
| | 25·72 | |
| Real ingredients of plant | 73·64 | |

Barley-straw belonging to the same crop from Essex.

1000 grains yielded 49 grains of ash.

100 grains of these ashes contain, of—

| | | |
|---|---|---|
| Sand and charcoal, extraneous | 8·59 | |
| Peroxide of iron, extraneous | 4·26 | |
| | 12·85 | |
| Silica | 41·81, or, excluding extraneous matter | 48·9 |
| Phosphoric acid | 4·18, or, excluding extraneous matter | 4·9 |
| Sulphuric acid | 0·67, or, excluding extraneous matter | 0·8 |
| Carbonic acid | 0·00 | 0·0 |
| Chloride of sodium | 9·58, or, excluding extraneous matter | 11·2 |
| Soda | 0·65, or, excluding extraneous matter | 0·7 |
| Potass | 18·49, or, excluding extraneous matter | 21·6 |
| Magnesia | 4·95, or, excluding extraneous matter | 5·7 |
| Lime | 5·18, or, excluding extraneous matter | 6·1 |
| | 98·36 | 99·9 |
| | 12·85 | |
| Real ingredients | 85·51 | |

The straw of the barley grown on the coast of Wales was not examined, but the ash of the grain from that quarter was found to contain, in 100 parts, 9·64 of potass, 1·32 of chloride of sodium, and only 0·84 of soda, the smaller proportion of potass being explained by the larger amount of extraneous matter present in the residuum left by it after calcination, than by the samples previously noticed.

The small proportion of soda, however, both in this, and in the former case in which the sample was obtained from the neighbourhood of the sea, seems to militate against the general conclusion deduced by Will, from his analysis of barley taken from the interior of Germany, as compared with the same brought from the Netherlands.

### Potatoes.

The crop grown in a recently manured portion of the Botanic Garden, separate from the spot set apart for the experiments, proving defective in quality, I selected as my standard a good mealy sort reared in the neighbourhood of Oxford, in the same kind of subsoil. The following will give the relative composition of this, and of the two crops obtained from the ground left for ten years unmanured, which, in the case of that styled the permanent, had borne potatoes for ten years consecutively, whilst in that styled the shifting, it had only borne them in 1844, having been occupied with the following plants on the nine years preceding, viz.—

1835. Delphinium consolida.
1836. Trifolium pratense.
1837. Nicotiana rustica.
1838. Valeriana Phu.
1839. Valeriana Phu.
1840. Linum usitatissimum.
1841. Solanum tuberosum.
1842. Papaver somniferum.
1843. Hordeum sativum.

*Standard Crop.*

| | | |
|---|---|---|
| Of the tubers, 1000 grains yielded about . . . | 7·6 | of ashes. |
| | 755·0 | of water. |
| | 236·4 | solid organic matter. |
| | 1000·0 | |

Overlooking the small amount of extraneous matter intermixed, the ash will of course represent the proportion which its inorganic constituents bear to the whole quantity.

Now 100 grains of this ash consisted of—

| | |
|---|---|
| Sand and charcoal, extraneous . . . | 5·93 |
| Peroxide of iron, extraneous . . . . | 6·85 |
| | 12·78 |
| Silica . . . . . . . . . . . . . | 5·81 |
| Phosphoric acid . . . . . . . . . | 9·68 |
| Sulphuric acid . . . . . . . . . | 5·23 |
| Carbonic acid . . . . . . . . . | 5·84 |
| Chloride of sodium . . . . . . . | 2·06 |
| Chloride of potassium . . . . . . | 6·67 |
| Potass . . . . . . . . . . . . | 37·99 |
| Magnesia . . . . . . . . . . . | 10·98 |
| Lime . . . . . . . . . . . . . | 2·71 |
| | 99·75 |
| | 12·78 |
| Real ingredients . . . . | 86·97 |

### *Permanent Crop of Potatoes.*

| | | |
|---|---|---|
| **Tubers, 1000 grains yielded** . . . . . . . . . . | 12·7 | of ash. |
| | 724·0 | of water. |
| | 263·3 | solid organic matter. |
| | 1000·0 | |

100 grains of this ash consisted of—

| | |
|---|---|
| Sand and charcoal, extraneous . . . . | 14·40 |
| Peroxide of iron, extraneous . . . . . | 3·30 |
| | 17·70 |
| Silica . . . . . . . . . . . . . . . | 1·57 |
| Phosphoric acid . . . . . . . . . . | 10·68 |
| Sulphuric acid . . . . . . . . . . . | 3·74 |
| Carbonic acid . . . . . . . . . . . | 10·68 |
| Chloride of sodium . . . . . . . . | 2·79 |
| Chloride of potassium . . . . . . . | 3·09 |
| Potass . . . . . . . . . . . . . . | 37·47 |
| Soda . . . . . . . . . . . . . . . | 0·00 |
| Magnesia . . . . . . . . . . . . . | 7·00 |
| Lime . . . . . . . . . . . . . . . | 3·64 |
| | 98·24 |
| | 17·70 |
| Real ingredients . . . . | 80·54 |

### *Shifting Crop of Potatoes.*

| | | |
|---|---|---|
| Of the tubers, 1000 grains yielded . . . . . . . . . | 10·8 | of ash. |
| | 719·0 | of water. |
| | 270·2 | solid organic matter. |
| | 1000·0 | |

100 grains of this ash consisted of—

| | |
|---|---|
| Sand and charcoal . . . . . . . . | 2·16 |
| Peroxide of iron . . . . . . . . . | 5·15 |
| | 7·31 |
| Silica . . . . . . . . . . . . . . | 6·60 |
| Phosphoric acid . . . . . . . . . | 15·13 |
| Sulphuric acid . . . . . . . . . . | 2·21 |
| Carbonic acid . . . . . . . . . . | 11·03 |
| Chloride of sodium . . . . . . . | 1·87 |
| Chloride of potassium . . . . . . | 0·00 |
| Potass . . . . . . . . . . . . . | 46·12 |
| Soda . . . . . . . . . . . . . . | 0·78 |
| Magnesia . . . . . . . . . . . . | 6·31 |
| Lime . . . . . . . . . . . . . . | 2·54 |
| | 99·88 |
| | 7·31 |
| Real ingredients . . . . . | 92·57 |

The above analyses of potatoes, it may be observed, agree more nearly with Boussingault than with Sprengel, as will appear by the following Table :—

| Ingredients. | Boussingault. | Sprengel. | Way. | | |
|---|---|---|---|---|---|
| | | | Permanent. | Shifting. | Standard. |
| Silica . . . . . . . | 5·6 | 1·0 | 1·95 | 7·150 | 6·67 |
| Phosphoric acid . . . | 11·3 | 4·8 | 13·30 | 16·200 | 11·15 |
| Sulphuric acid . . . | 7·1 | 6·5 | 4·66 | 2·370 | 6·00 |
| Carbonic acid . . . | 13·4 | 0·0 | 13·30 | 11·900 | 6·70 |
| Chloride of sodium . . | 0·0 | 0·0 | 3·43 | 1·950 | 2·30 |
| Chloride of potassium . | 0·0 | 0·0 | 0·00 | 0·000 | 7·60 |
| Soda . . . . . . . | traces. | 28·5 | 0·00 | 0·840 | 0·00 |
| Potass . . . . . . . | 51·5 | 48·2 | 46·60 | 50·00 | 43·80 |
| Magnesia . . . . . . | 5·4 | 3·9 | 8·70 | 6·85 | 12·65 |
| Lime . . . . . . . | 1·8 | 4·0 | 4·54 | 2·70 | 3·10 |

The correspondence between the standard crop analysed by Mr. Way and the one analysed by Boussingault, is in many particulars exceedingly close ; there is indeed an excess of magnesia and some little deficiency of potass, but if the potassium present in 7·6 of chloride (which is equivalent to 4·0) be represented as potass, it will amount to 4·8, which, added to 43·8, brings up the proportion of potass to 48·6, or to more than that present in the permanent crop.

### Turnips.

The next kind of crop which we analysed was the turnips, and the following were the results obtained :—

Standard sort from the neighbourhood of Oxford, contained about 10 of water, and 1 of organic matter.

1000 grains yielded 3·18 of ashes ; 100 grains of which consisted of—

| | |
|---|---|
| Sand and charcoal . . . . . . . . | 5·28 |
| Peroxide of iron . . . . . . . . | 11·91 |
| | 17·16 |
| Silica . . . . . . . . . . . . . | 3·81 |
| Phosphoric acid . . . . . . . . | 12·63 |
| Sulphuric acid . . . . . . . . . | 7·17 |
| Carbonic acid . . . . . . . . . | 7·04 |
| Chloride of sodium . . . . . . . | 4·83 |
| Soda . . . . . . . . . . . . . | 2·57 |
| Potass . . . . . . . . . . . . | 31·62 |
| Magnesia . . . . . . . . . . . | 3·18 |
| Lime . . . . . . . . . . . . . | 11·54 |
| | 101·55 |
| | 17·16 |
| Real ingredients . . . . | 84·39 |

*Turnips.*

Shifting crop.

| | |
|---|---|
| Sand and charcoal | 4·01 |
| Peroxide of iron | 3·81 |
| | 7·82 |
| Silica | 3·30 |
| Phosphoric acid | 10·77 |
| Sulphuric acid | 9·43 |
| Carbonic acid | 8·66 |
| Chloride of sodium | 0·00 |
| Chloride of potassium | 5·40 |
| Potass | 38·46 |
| Magnesia | 5·08 |
| Lime | 10·44 |
| | 99·42 |
| | 7·82 |
| Real ingredients | 91·60 |

*Turnips.*

Permanent crop..

| | |
|---|---|
| Sand and charcoal | 3·92 |
| Peroxide of iron | 2·80 |
| | 6·72 |
| Silica | 2·67 |
| Phosphoric acid | 12·80 |
| Sulphuric acid | 11·07 |
| Carbonic acid | 9·75 |
| Chloride of sodium | 1·74 |
| Soda | 0·00 |
| Potass | 39·44 |
| Magnesia | 3·83 |
| Lime | 11·81 |
| | 99·73 |
| | 6·72 |
| Real ingredients | 93·01 |

Here also there is a pretty near coincidence between the analysis of Mr. Way and that of Boussingault, excepting in the amount of phosphoric acid, which corresponds nearly to that reported by Sprengel, with whom however in other respects there is but little agreement, as will appear from the following Table:—

| Ingredients. | Boussingault. | Sprengel. | Way. | | |
|---|---|---|---|---|---|
| | | | Permanent. | Shifting. | Standard. |
| Silica | 6·4 | 7·8 | 2·87 | 3·60 | 4·5 |
| Phosphoric acid | 6·0 | 14·0 | 13·70 | 11·80 | 14·9 |
| Sulphuric acid | 10·9 | 7·9 | 11·80 | 10·30 | 8·5 |
| Carbonic acid | 0·0 | 0·0 | 10·10 | 9·40 | 8·3 |
| Chloride of sodium | 0·0 | 0·0 | 1·83 | 0·00 | 5·7 |
| Chloride of potassium | 0·0 | 0·0 | 0·00 | 5·90 | 0·0 |
| Soda | 4·1 | 21·0 | 0·00 | 0·00 | 3·1 |
| Potass | 33·7 | 14·0 | 42·40 | 42·00 | 37·4 |
| Magnesia | 4·3 | 4·3 | 4·10 | 5·60 | 3·8 |
| Lime | 10·9 | 24·4 | 12·81 | 11·30 | 13·6 |

| | Boussingault. | Sprengel. | Way. | | |
|---|---|---|---|---|---|
| | | | Permanent. | Shifting. | Standard. |
| Potass | 33·7 | 21·0 | 42·40 | 45·74† | 37·40 |
| Soda | 4·1 | 14·0 | 1·14* | 0·00 | 6·16‡ |
| Alkalies | 37·8 | 35·0 | 43·54 | 45·74 | 43·56 |

## Hemp.

Standard crop grown in the Botanic Garden apart from the portion reserved for the experiments.

100 grains of the crop left 6·1 of ashes, 100 grains of which contained of—

| | |
|---|---|
| Charcoal and sand | 7·48 |
| Peroxide of iron | 2·78 |
| | 10·26 |
| Silica | 5·58 |
| Phosphoric acid | 5·44 |
| Sulphuric acid | 1·09 |
| Carbonic acid | 19·81 |
| Chloride of sodium | 1·72 |
| Soda | 0·98 |
| Potass | 13·71 |
| Magnesia | 7·67 |
| Lime | 34·03 |
| | 100·29 |
| | 10·26 |
| Real ingredients | 90·03 |

---

* Viz. Ch. Sod. 1·83 = Soda 1·14.

† Viz. Potass .............. 42·00
Ch. Pot. 5·9 = Potass ...... 3·74
45·74

‡ Viz. Soda ................ 3·10
Ch. Sod. ........... 5·7 = 3·06
6·16

### *Hemp.*

Shifting crop.

100 parts yielded 7·01 of ash, 100 parts of which consisted of—

| | |
|---|---|
| Sand and charcoal | 8·30 |
| Peroxide of iron | 3·78 |
| | 12·08 |
| Silica | 8·71 |
| Phosphoric acid | 5·68 |
| Sulphuric acid | 0·73 |
| Carbonic acid | 20·10 |
| Chloride of sodium | 0·63 |
| Chloride of potassium | 0·00 |
| Soda | 0·14 |
| Potass | 7·49 |
| Magnesia | 5·19 |
| Lime | 39·00 |
| | 99·75 |
| | 12·08 |
| Real ingredients | 87·67 |

### *Hemp.*

Permanent crop.

100 parts yielded 6·00 of ash, 100 parts of which consisted of—

| | |
|---|---|
| Sand and charcoal | 10·40 |
| Peroxide of iron | 3·94 |
| | 14·34 |
| Silica | 8·39 |
| Phosphoric acid | 4·50 |
| Sulphuric acid | 1·09 |
| Carbonic acid | 19·78 |
| Chloride of sodium | 0·43 |
| Soda | 0·06 |
| Potass | 7·25 |
| Magnesia | 2·18 |
| Lime | 40·10 |
| | 98·12 |
| | 14·34 |
| Real ingredients | 83·78 |

The following will give a tabular view of the composition of the above three crops in 100 parts, after deducting the extraneous matters present in the ash.

| Ingredients. | Standard. | Shifting. | Permanent. |
|---|---|---|---|
| Silica | 6·13 | 9·95 | 10·00 |
| Phosphoric acid. | 6·00 | 6·50 | 5·35 |
| Sulphuric acid | 2·00 | 0·83 | 1·20 |
| Carbonic acid | 21·79 | 23·00 | 23·50 |
| Chloride of sodium | 1·89 | 0·72 | 0·47 |
| Soda | 1·08 | 0·16 | 0·07 |
| Potass | 15·08 | 8·55 | 8·62 |
| Magnesia | 8·43 | 5·95 | 2·62 |
| Lime | 37·40 | 44·60 | 47·60 |
|  | 99·80 | 100·26 | 100·00 |

## FLAX.

Standard crop grown in the Botanic Garden apart from the spot reserved for the experiments.

100 grains of the crop, including the ripened seeds, yielded 10·7 of ash, of which latter 100 parts contained—

| | |
|---|---|
| Sand and charcoal | 12·02 |
| Peroxide of iron | 3·42 |
|  | 15·44 |
| Silica | 1·77 |
| Phosphoric acid | 6·85 |
| Sulphuric acid | 5·10 |
| Carbonic acid | 15·69 |
| Chloride of sodium | 2·43 |
| Chloride of potassium | 6·04 |
| Soda | 0·00 |
| Potass | 21·73 |
| Magnesia | 3·89 |
| Lime | 18·30 |
|  | 97·24 |
|  | 15·44 |
| Real ingredients | 81·80 |

*Flax.*

Shifting crop.

100 grains of the crop yielded 8·0 of ashes, 100 grains of which consisted of—

| | |
|---|---|
| Sand and charcoal | 13·15 |
| Peroxide of iron | 5·41 |
| | 18·56 |
| Silica | 1·82 |
| Phosphoric acid | 6·77 |
| Sulphuric acid | 4·18 |
| Carbonic acid | 17·38 |
| Chloride of sodium | 1·58 |
| Soda | 1·05 |
| Potass | 20·51 |
| Magnesia | 4·72 |
| Lime | 21·56 |
| | 98·13 |
| | 18·56 |
| Real ingredients | 79·57 |

*Flax.*

Permanent crop.

100 grains of the crop yielded 6·675 of ash, 100 grains of which consisted of—

| | |
|---|---|
| Sand and charcoal | 7·05 |
| Peroxide of iron | 8·01 |
| | 15·06 |
| Silica | 6·55 |
| Phosphoric acid | 6·55 |
| Sulphuric acid | 3·12 |
| Carbonic acid | 12·20 |
| Chloride of sodium | 1·14 |
| Soda | 5·87 |
| Potass | 11·05 |
| Magnesia | 4·68 |
| Lime | 33·59 |
| | 99·81 |
| | 15·06 |
| Real ingredients | 84·75 |

The following will show the composition of the three crops of flax, after deducting the extraneous matters present in the ash.

| Ingredients. | Standard. | Shifting. | Permanent. |
|---|---|---|---|
| Silica | 2·16 | 2·3 | 7·3 |
| Phosphoric acid | 8·40 | 8·5 | 7·3 |
| Sulphuric acid | 6·20 | 5·3 | 3·7 |
| Carbonic acid | 19·10 | 21·9 | 14·4 |
| Chloride of sodium | 2·93 | 2·0 | 1·4 |
| Chloride of potassium | 7·35 | | |
| Soda | | 1·3 | 6·9 |
| Potass | 26·50 | 25·8 | 13·0 |
| Magnesia | 4·76 | 5·9 | 5·5 |
| Lime | 22·30 | 27·0 | 40·0 |
| | 99·70 | 100·0 | 99·5 |

### Beans.

Standard crop grown in a part of the Botanic Garden distinct from the portion set apart for the experiments.

100 grains yielded 6·45 of ash, 100 grains of which consisted of—

| | |
|---|---|
| Sand and charcoal | 12·00 |
| Peroxide of iron | 2·33 |
| | 14·33 |
| Silica | 2·44 |
| Phosphoric acid | 7·77 |
| Sulphuric acid | 2·95 |
| Carbonic acid | 17·38 |
| Chloride of sodium | 2·58 |
| Chloride of potassium | 0·91 |
| Soda | 0·00 |
| Potass | 30·37 |
| Magnesia | 2·69 |
| Lime | 17·17 |
| | 98·57 |
| | 14·33 |
| Real ingredients | 84·26 |

*Beans.*

Shifting crop.

100 parts of crop yielded 5·7 of ashes, 100 parts of which consisted of—

| | |
|---|---|
| Sand and charcoal | 8·24 |
| Peroxide of iron | 3·77 |
| | 12·01 |
| Soluble silica | 3·97 |
| Phosphoric acid | 3·83 |
| Sulphuric acid | 2·49 |
| Carbonic acid | 18·45 |
| Chloride of sodium | 1·23 |
| Soda | 0·22 |
| Potass | 20·56 |
| Magnesia | 3·79 |
| Lime | 33·87 |
| | 88·41 |
| | 12·01 |
| Real ingredients | 76·40 |

*Beans.*

Permanent crop.

100 parts of crop yielded 4·4 of ash, 100 parts of which consisted of—

| | |
|---|---|
| Sand and charcoal, extraneous | 6·13 |
| Peroxide of iron, extraneous | 4·24 |
| | 10·37 |
| Soluble silica | 4·05 |
| Phosphoric acid | 3·29 |
| Sulphuric acid | 1·96 |
| Carbonic acid | 19·87 |
| Chloride of sodium | 1·00 |
| Soda | 7·00 |
| Potass | 12·77 |
| Magnesia | 3·63 |
| Lime | 35·76 |
| | 99·70 |
| | 10·37 |
| Real ingredients | 89·33 |

The following Table will show the composition of the three crops of beans, after deducting the extraneous matters present in the ash.

| Ingredients. | Standard. | Shifting. | Permanent. |
|---|---|---|---|
| Soluble silica . . . . | 2·90 | 4·48 | 4·50 |
| Phosphoric acid. . . . | 9·25 | 4·32 | 3·68 |
| Sulphuric acid . . . . | 3·50 | 2·80 | 2·19 |
| Carbonic acid . . . . | 20·70 | 20·85 | 22·20 |
| Chloride of sodium. . . | 3·17 | 1·38 | 1·12 |
| Chloride of potassium . . | 1·08 | 0·00 | 0·00 |
| Soda . . . . . . . . | 0·00 | 0·24 | 7·80 |
| Potass . . . . . . . . | 36·10 | 23·20 | 14·20 |
| Magnesia . . . . . . . | 3·20 | 4·28 | 4·06 |
| Lime . . . . . . . . | 20·30 | 38·20 | 40·00 |
| | 100·00 | 99·75 | 99·75 |

Having now, with reference to the six plants above-mentioned, stated, not only the amount of every year's crop, but also the composition of the last of each which had been obtained, we seem to be in a position to calculate the amount of the several inorganic ingredients contained in them, which will have been abstracted from the ground during the time the experiments were carried on.

This indeed is a question of little interest, so far as regards the acids and bases that are predominant ingredients in the soil, but in the case of the alkalies, the magnesia, and the phosphates, which exist there in more limited quantity, its determination may afford us a clew towards the main object of our inquiry, namely, the cause of the falling off of a crop after frequent repetition.

In the case of the barley, it will be seen, that the produce of the same plot of ground amounted in the course of ten years to 289·65 lbs., including straw as well as grain, and that, taking the last year's crop as the criterion, this quantity would have yielded 25·2 lbs. of ash.

For as 100—8·7—289·65—25·2.

Now 25·2 lbs. of ash would contain nearly as follows, according to the analyses given above:—

| | |
|---|---|
| Sand and charcoal<br>Peroxide of iron } extraneous . . . | 6·25 |
| Silica . . . . . . . . . . . . | 6·30 |
| Phosphoric acid . . . . . . . . | 1·84 |
| Sulphuric acid . . . . . . . . . | 0·53 |
| Carbonic acid . . . . . . . . . | 0·47 |
| Chloride of sodium . . . . . . . | 1·18 |
| Potass . . . . . . . . . . . . | 4·36 |
| Magnesia . . . . . . . . . . . | 1·15 |
| Lime. . . . . . . . . . . . . | 3·52 |
| | 25·60 |

On the other hand, the shifting crops of barley, which in ten years amounted to 421 lbs., and which, taking as our criterion the amount of ash yielded the last year (1844), had drawn from the land 26·31 lbs. of inorganic matter (the sand, charcoal, and peroxide of iron, drawn from other sources having been deducted), would have abstracted from the soil in ten years, as follows:—

| | |
|---|---|
| Sand and charcoal<br>Peroxide of iron } extraneous | 6·175 |
| Silica | 9·300 |
| Phosphoric acid | 2·370 |
| Sulphuric acid | 0·600 |
| Carbonic acid | 0·366 |
| Chloride of sodium | 0·364 |
| Potass | 4·220 |
| Magnesia | 0·915 |
| Lime | 1·960 |
| | 26·270 |

Proceeding now to the second case, that of the potatoes, we find the amount of the produce, in the case of the permanent crop, in nine years to have been 620·8 lbs., yielding 7·37 of ashes, of which, however, about 1·37 were extraneous. Consequently during that period the inorganic constituents, abstracted from the soil, and contained in 6 lbs. of real ash, would be as follows:—

| | |
|---|---|
| Silica | 0·11 |
| Phosphoric acid | 0·80 |
| Sulphuric acid | 0·27 |
| Carbonic acid | 0·80 |
| Chloride of sodium | 0·20 |
| Chloride of potassium | 0·23 |
| Potass | 2·80 |
| Magnesia | 0·52 |
| Lime | 0·27 |
| | 6·00 |

On the other hand, we find, in the case of the shifting crop, the average of nine years' produce to be 89·1, or nearly 802 lbs. for the whole period, yielding of ashes about . . . . . . . . . . . . . . . . . . . 7·3 lbs.
from which must be deducted, as extraneous matter, about . . . . . . . 0·7

Leaving for real ash . . . . . 6·6

and containing the following constituents:—

| | |
|---|---|
| Silica | 0·472 |
| Phosphoric acid | 1·070 |
| Sulphuric acid | 0·157 |
| Carbonic acid | 0·785 |
| Chloride of sodium | 0·130 |
| Potass | 3·300 |
| Soda | 0·055 |
| Magnesia | 0·452 |
| Lime | 0·178 |
| | 6·599 |

In the case of the next crop, the turnips, I have not sufficient data to determine with exactness the amount of inorganic ingredients extracted from the soil, having omitted to weigh the bulbs, from which the ash, in the case both of the permanent and shifting crops, was derived.

I find, however, that 1000 parts of a good sample from the neighbourhood of Oxford yielded 3·15 of ash, of which about 0·55 was extraneous, so that 2·6 grains will represent the amount of inorganic constituents really present.

The bulbs obtained from the permanent crop in ten years amounted to about 1008 lbs.; so that the inorganic constituents extracted from the soil in this instance may be reckoned at about 2·62 lbs.

Now 2·62 lbs. of inorganic matter would, according to the previous data, consist of the following ingredients, viz.

| | lbs. |
|---|---|
| Silica | 0·075 |
| Phosphoric acid | 0·360 |
| Sulphuric acid | 0·310 |
| Carbonic acid | 0·273 |
| Chloride of sodium | 0·050 |
| Potass | 1·110 |
| Soda | 0·000 |
| Magnesia | 0·110 |
| Lime | 0·332 |
| | 2·620 |

The shifting crop of turnips in the same period yielded of bulbs 1765 lbs., which, according to the same calculation, would have produced 4·58 of real ash.

For as 1008—262—1765—4·58.

Now 4·58 lbs. of ash would contain the following proportions of inorganic constituents, viz.

| | |
|---|---|
| Silica | 0·165 |
| Phosphoric acid | 0·540 |
| Sulphuric acid | 0·470 |
| Carbonic acid | 0·430 |
| Chloride of potassium | 0·270 |
| Potass | 1·930 |
| Magnesia | 0·255 |
| Lime | 0·520 |
| | 4·580 |

The next crop I shall consider is hemp, of which the permanent crop, according to the statements given in the first part of this paper, would have amounted in nine years to 271·25 lbs., or 30·13 lbs. per annum, yielding of ash 16·27 lbs.

For as 100—6·0—271·25—16·27.

Now 16·27 lbs. of ash would contain
of extraneous matter about 2·27
leaving 14·00 of inorganic principles belonging to the plant, which would consist of—

| | |
|---|---|
| Silica | 1·30 |
| Phosphoric acid | 0·70 |
| Sulphuric acid | 0·17 |
| Carbonic acid | 3·07 |
| Chloride of sodium | 0·06 |
| Soda | 0·08 |
| Potass | 1·10 |
| Magnesia | 1·40 |
| Lime | 6·12 |
| | 14·00 |

Now the average of the shifting crops for seven crops was 40 lbs., and as the ash obtained was about 7 per cent. its whole amount would have been 2·8 lbs.

| | lbs. |
|---|---|
| Or in seven years (2·8×7)= | 19·6 |
| Of which the extraneous matter would be about | 2·3 |
| Leaving of inorganic principles extracted from the earth in seven years | 17·3 |
| Or, if in seven years—17·3—nine years | 22·17 |

Now 17·3 lbs. of inorganic principles consist of

| | | |
|---|---|---|
| Silica | 1·70 | 2·19 |
| Phosphoric acid | 1·18 | 1·52 |
| Sulphuric acid | 0·14 | 0·18 |
| Carbonic acid | 3·96 | 5·10 |
| Chloride of sodium | 0·12 | 0·15 |
| Soda | 0·03 | 0·04 |
| Potass | 1·47 | 1·90 |
| Magnesia | 1·00 | 1·29 |
| Lime | 7·60 | 9·80 |
| | 17·20 | 22·17 |

I next proceed to the flax, which in ten years produced, as we have seen, an amount of crop equal to 126 lbs., yielding of ashes 8·4 lbs.
of which 1·26 was extraneous.

Leaving of real ash 7·14, which would consist of—

| | |
|---|---|
| Silica | 0·520 |
| Phosphoric acid | 0·520 |
| Sulphuric acid | 0·264 |
| Carbonic acid | 1·020 |
| Chloride of sodium | 0·099 |
| Soda | 0·490 |
| Potass | 0·925 |
| Magnesia | 0·390 |
| Lime | 2·850 |
| | 7·078 |

Now the average of ten crops of flax, cultivated in different plots of the same garden, was 22·7 lbs., yielding 1·816 of ashes, = in ten years 18·16 lbs., of which 3·36 lbs. were extraneous, leaving 14·8 lbs. of real ash, which would consist of the following ingredients:—

| | |
|---|---|
| Silica | 0·34 |
| Phosphoric acid | 1·25 |
| Sulphuric acid | 0·78 |
| Carbonic acid | 3·22 |
| Chloride of sodium | 0·30 |
| Soda | 0·20 |
| Potass | 3·80 |
| Magnesia | 0·87 |
| Lime | 4·00 |
| | 14·76 |

The last of the crops made the subject of examination was the beans, where the aggregate of ten years' produce, in the case of the permanent crop, was 247 lbs., which would have yielded 10·8 lbs. of ashes.

Of this, however, about 1·1 would consist of extraneous matter.

Leaving 9·7 of real ash,
consisting of the following ingredients:—

| | |
|---|---|
| Silica | 0·44 |
| Phosphoric acid | 0·36 |
| Sulphuric acid | 0·22 |
| Carbonic acid | 2·13 |
| Chloride of sodium | 0·12 |
| Soda | 0·76 |
| Potass | 1·37 |
| Magnesia | 0·40 |
| Lime | 3·90 |
| | 9·70 |

In the case of the shifting crop of beans the produce of ten years gives an aggregate of 336 lbs., yielding of ash 19·15 lbs.,

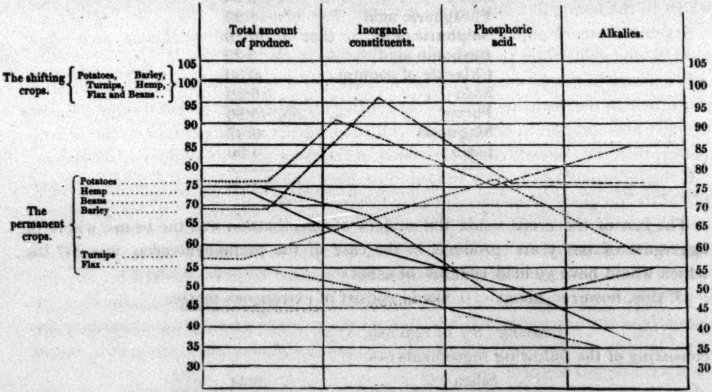
of which, however, about 2·30 was extraneous,

leaving 16·85 of real ash,

which would contain, of—

| | |
|---|---|
| Silica | 0·757 |
| Phosphoric acid | 0·723 |
| Sulphuric acid | 0·470 |
| Carbonic acid | 3·500 |
| Chloride of sodium | 0·235 |
| Soda | 0·044 |
| Potass | 3·900 |
| Magnesia | 0·725 |
| Lime | 6·420 |
| | 16·774 |

Diagram showing the relation between the Permanent and the Shifting Crops.



Before we proceed to inquire, whether the difference in the average amount of produce obtained under these two modes of cultivation arose from a deficiency of the organic, or of the inorganic materials present in the soil, it may be worth while to present a tabular view of the numerical relation subsisting between the permanent and shifting crops in each instance, with respect to the entire crop, to the entire amount of inorganic matter, and to the proportions of phosphoric acid and of alkalies present in each.

| | Total amount of produce. | | Inorganic constituents. | | Phosphoric acid. | | Alkalies. | |
|---|---|---|---|---|---|---|---|---|
| | Permanent. | Shifting. | Permanent. | Shifting. | Permanent. | Shifting. | Permanent. | Shifting. |
| Barley.... | 69·0 | 100·0 | 96·5 | 100·0 | 77·0 | 100·0 | 77·0 | 100·0 |
| Potatoes.. | 77·5 | 100·0 | 91·0 | 100·0 | 75·0 | 100·0 | 85·0 | 100·0 |
| Turnips .. | 57·0 | 100·0 | .... | .... | 77·0 | 100·0 | 58·0 | 100·0 |
| Hemp.... | 75·0 | 100·0 | 63·5 | 100·0 | 46·8 | 100·0 | 55·0 | 100·0 |
| Flax..... | 55·5 | 100·0 | 48·0 | 100·0 | 41·6 | 100·0 | 35·0 | 100·0 |
| Beans.... | 73·0 | 100·0 | 58·0 | 100·0 | 50·0 | 100·0 | 36·0 | 100·0 |

The results in the two first instances would seem to lead to opposite conclusions from those suggested by the three latter, inasmuch as, whilst in the barley and the potatoes, the difference between the amount of inorganic constituents in the two cases was much less than that between the permanent and shifting crop collectively taken; in the hemp, flax and beans the contrary remark applies.

If we take the phosphoric acid, we find also that in the barley, and turnips, it stands in a higher ratio to the other constituents in the permanent, than in the shifting crop, whilst in the hemp, flax and beans, it stands in a much lower one.

A similar remark applies to the alkalies, so that no general conclusion, as it might seem, is deducible from these premises.

It appears to me, however, that the existence of a larger relative amount of phosphoric acid in the permanent than in the shifting crops of barley and of turnips, affords a stronger presumption in favour of a certain dependence of the produce on the organic matter, than the opposite result arrived at in the three other cases does of the reverse.

If the falling-off of the crop in these instances had arisen from a deficiency of certain of its inorganic principles, such for instance as the phosphates or the alkalies, at least a corresponding reduction in these latter might have been expected to have been found in the ashes of the one which proved deficient in quantity; whilst on the other hand, if the deficiency of organic matter be supposed to have checked the development of particular parts, as, for example, of the seeds, it might thereby affect the character of the ashes obtained, and thus a smaller amount be abstracted, without any actual failure, in the supply afforded by the soil to the plants that grew in it, taking place with regard to them.

I am led to this opinion, by the result of an examination, which I requested Mr. Way to institute, into the nature of the inorganic constituents present in ordinary gluten, and in starch.

The first, obtained from wheat, yielded about three parts of inorganic matter in the 1000 parts, which latter contained as much as 33 per cent. of phosphoric acid combined with lime, and a trace of magnesia, but no carbonate of lime*.

---

* I found also that the bran contained a larger proportion of silica than the albumen of the grain itself, and we know that the proportion of these several parts, one to the other, varies considerably in different samples of flour.

The latter, obtained from potatoes, yielded about 3·43 parts of inorganic matter in the 1000, of which only 4·77 per cent. was phosphoric acid, whilst 82·48 was carbonate of lime.

Thus, in the case of wheat, any condition of things which should check the formation of gluten, would diminish the quantity of phosphoric acid present in the ashes of this plant, even though the soil might contain an abundant supply of that ingredient; and as the formation of gluten is promoted by the presence of manures abounding in ammoniacal salts*, so it may easily happen, that this principle should be deficient where such manures are too sparingly administered.

In a similar way, a variation in the constituents of barley and other crops may be supposed to arise, not only from a larger or smaller supply of inorganic principles in the soil, in the manner that Liebig has so lucidly explained to us, but likewise from a more plentiful exhibition of those products of the decomposition of organic bodies, which favour the development of particular organs, or of certain of the proximate principles which the latter contain.

Which, however, of these two suppositions applies to the cases now under consideration, will be better seen, when we have considered the composition of the soil in which they grew, as determined by analysis.

## PART III.

### *On the chemical composition of the soil in which the crops were grown, and on the proportion of its ingredients that were available for the purposes of vegetation.*

The chief difficulty, which occurs with respect to the analysis of a soil, relates to the determination of those ingredients which, like the phosphates and the alkalies, exist in minute proportions, and which accordingly appear to have been overlooked by Davy, and others, who first applied themselves to the subject of agricultural chemistry.

It will not be necessary therefore to take up the time of this Society, by giving a detailed account of the method pursued by Mr. Way in his examination of the soils of which I wished to learn the composition; it may be sufficient to state, that after separating the several portions, one from the other, by the mechanical method pointed out by Mr. Rham, and determining the relation which the coarser bore to the finer, the latter, which alone were supposed capable of imparting any nourishment to plants, at least within a limited period, was submitted to the usual course of examination pursued by chemists.

To ascertain the phosphates however, a distinct and a much larger portion of the soil was operated upon, not less than 2000 grains being taken for the purpose, and this was digested for five hours in water acidulated with muriatic acid, the flask employed for the purpose being fitted up with a funnel attached to its neck, in the manner recommended by Dr. URE, for the purpose of condensing the acid which might be disengaged in vapour, and restoring it to the body of the vessel *.

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* See Hermbstadt's experiments quoted in the third of my Lectures on Agriculture, and Sir H. Davy's Lectures on Agricultural Chemistry.

The liquor, after being filtered, was evaporated to dryness, so as to dispel the greater part of the acid.

The residuum was then treated with water, and an excess of ammonia was added, by which the iron, alumina, and phosphate of lime were thrown down.

The whole was then carried to dryness, and gently ignited, by which means the greater part of the iron and of the alumina is rendered insoluble in dilute acids, which take up the phosphate of lime.

The solution was then treated with ammonia so long as any precipitate was thrown down, and the latter digested with dilute alcohol mixed with sulphuric acid, by which any alumina and iron that had been precipitated were converted into soluble salts, whilst any lime in combination with phosphoric acid would remain as an insoluble sulphate, from the amount of which, when well-washed and dried, that of the phosphate present in the soil admits of being calculated.

After ammonia had thrown down the alumina, iron, and phosphate of lime, the alkalies existing in the ash would still remain in the solution.

The latter was therefore again evaporated to dryness, and the ammoniacal salts driven off.

The residue was then treated with water, boiled and filtered, after which a solution of carbonate of ammonia, to which a little pure ammonia had been added, was introduced into the liquor that came through. The remainder of the earths were thus thrown down, and nothing remained in solution except the alkalies. After the ammoniacal salts had been expelled by heat, the mixed chlorides of potassium and sodium were separated in the usual way by chloride of platinum.

Such then was the method pursued for determining the nature and proportions of those ingredients, which, if not available for the purposes of vegetation at the present time, may at least be regarded as likely to prove useful to them within no very distant period, as being separable, by dilute muriatic acid, from the mass of the earth.

The soil of that part of the garden, in which the experiments above detailed had been conducted, varied in depth from three to four feet, and rested upon a stiff clay, of which the subsoil in the valley of Oxford consists, wherever it is not overlaid by gravel.

It was chiefly made ground, brought in to elevate the level of the garden above that to which the contiguous river rises during the winter floods, and about a year antecedent to the commencement of the experiments it had been manured with stable dung.

I have already expressed my regret, that no analysis was made of it until the present year, at which time the experiments had been already brought to a close.

In a neighbouring part of the garden, which appeared to be similarly circumstanced to that which had been set apart for the experiments, except that it had been recently

---

* Journal of the Agricultural Society, vol. v. p. 617.

manured, the ingredients of the impalpable portion of the soil, which had passed through the meshes of a fine sieve, were found by Mr. Way to be as follows:—

| | |
|---|---|
| Sand and clay | 410·44 |
| Organic matter | 103·96 |
| Silica | 95·06 |
| Lime | 139·53 |
| Peroxide of iron | 98·33 |
| Alumina | 35·60 |
| Carbonic acid | 106·10 |
| Sulphuric acid | 1·82 |
| Chlorine | a trace. |
| Magnesia | ·46 |
| Potass | 2·58 |
| Soda | 1·18 |
| Phosphate of lime | ·73 |
| | 995·79 |
| Loss | 4·21 |
| Coarse sand | 890·00 |
| Stones and pebbles | 870·00 |
| | 2760·00 |

The soil of the garden in which the experiments had been conducted was also subjected to a similar examination, the plot which had grown a crop of barley for ten years without manure having been selected.

The following were the results:—

| | |
|---|---|
| Sand and clay | 407·00 |
| Organic matter | 75·00 |
| Silica | 109·20 |
| Lime | 144·17 |
| Peroxide of iron | 103·80 |
| Magnesia | ·85 |
| Alumina | 25·00 |
| Sulphuric acid | 1·65 |
| Carbonic acid | 125·69 |
| Potass | 2·91 |
| Soda | ·29 |
| Phosphate of lime | ·80 |
| Chlorine | a trace. |
| Loss | 3·64 |
| | 1000·00 |
| Coarse sand | 810·00 |
| Stones and pebbles | 660·00 |
| | 2470·00 |

In another of the beds which had reared a permanent crop, viz. that of potatoes, the proportion of the phosphates, alkalies, and magnesia did not appear to vary much, the analysis of 1000 grains of the finer portion sifted, affording the following results:—

| | |
|---|---|
| Phosphate of lime . . . | 0·86 |
| Potass . . . . . . . . | 1·57 |
| Soda . . . . . . . . . | 0·27 |
| Magnesia . . . . . . . | 0·82 |
| The organic matter here was | 53·00 |

A third of the beds in the same garden, which had borne a crop of turnips for ten years, exhibited rather a remarkable anomaly, as the phosphates exceeded in quantity considerably that present in the contiguous garden, the results being as follows:—

| | |
|---|---|
| Potass, in 1000 parts . . | 0·46 |
| Soda . . . . . . . . . | 0·74 |
| Phosphate of lime . . . | 1·62 |
| Organic matter . . . . | 110·80 |

It will be seen, that the permanent crop of turnips in ten years would have extracted from the soil only 0·36 of phosphoric acid, whilst the barley in the same time had extracted 1·84, and the potatoes 0·80; hence perhaps the difference in the quantity present in the soil.

One only of the plots of ground, which had grown a succession of different crops for ten years without manure, was examined*, and the proportion of the above ingredients found in it appeared to be as follows, viz.—

| | |
|---|---|
| Potass in 100 grains . . | 1·96 |
| Soda . . . . . . . . . | 1·12 |
| Phosphate of lime . . . . | 0·33 |
| Organic matter . . . . . | 76·50 |

It will be seen from the table in the following page, that, taking as our standard the composition of the contiguous garden, of which the analysis is first reported, and in which the proportion of phosphoric acid would seem to be lower than it is in most of the plots of ground experimented upon, even after ten years' cropping without manure (judging from the few which were examined), a sufficient quantity of the above ingredient existed, to supply what would be necessary for nineteen crops of barley, of the same amount as the average of those obtained from the permanent bed, and of the same quality as that produced in 1844.

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* The crops were, barley in 1844, hemp in 1843, buckwheat in 1842, tobacco in 1841, parsley in 1840 and 1839, mint in 1838 and 1837, parsley in 1836, and beans in 1835.

**In the following Table the results are all reduced to one standard.**

**1000 grains of the soil.**

| Ingredients. | Contiguous garden. | Permanent bed of barley. | Permanent bed of potatoes. | Permanent bed of turnips. | Bed which had borne a succession of ten crops without manure. |
|---|---|---|---|---|---|
| Stones and pebbles . . | 315·000 | 267·000 | | | |
| Coarse sand . . . . . | 322·000 | 328·000 | | | |
| Fine sand and clay . . | 149·000 | 165·000 | | | |
| Organic matter . . . . | 37·600 | 30·400 | 21·400 | 44·8* | 31·000 |
| Silica, soluble . . . . | 34·400 | 44·000 | | | |
| Lime . . . . . . . . | 50·500 | 58·000 | | | |
| Peroxide of iron . . . | 35·500 | 41·800 | | | |
| Alumina, soluble . . . | 12·800 | 10·100 | | | |
| Carbonic acid . . . . | 38·400 | 50·500 | | | |
| Sulphuric acid . . . . | 0·660 | 0·665 | | | |
| Chlorine . . . . . . . | a trace. | a trace. | | | |
| Magnesia. . . . . . . | 0·167 | 0·344 | 0·332 | | |
| Potass. . . . . . . . | 0·930 | 1·180 | 0·640 | 0·186 | 0·790 |
| Soda . . . . . . . . | 0·428 | 0·117 | 0·109 | 0·300 | 0·470 |
| Phosphate of lime . . . | 0·265 | 0·322 | 0·346 | 0·656 | 0·133 |
| | 997·650 | 997·428 | | | |

For one cubic foot of the soil of the garden was found to weigh eighty-two lbs., from which it follows, that an area of 100 square feet to the depth of three feet (which is less than the average depth of the soil in the garden), would contain 24,600 lbs. of soil, which at 1·0 gr. to 1 lb. of soil would give an amount of phosphoric acid equal to 3·5 lbs.

Now it has been calculated (page 230) that the quantity of phosphoric acid extracted from the soil in ten years did not exceed 1·84 lb., so that the permanent bed of barley, which contains at present 0·8 of phosphate of lime, or 0·4 of phosphoric acid, would not have possessed before the cropping more than 1·26 of phosphate, or 0·63 of phosphoric acid, in the 1000 grains.

With respect to the alkalies, we shall find by the same mode of calculation that the medical garden contains in 100 square feet—

| | lbs. |
|---|---|
| Potass . . . . . . | 6·9 |
| Soda . . . . . . | 2·9 |

And as each permanent crop of barley in the average extracted no more than of—

| | |
|---|---|
| Potass . . . . . | 0·436 |
| Soda . . . . . . | 0·064, |

(deduced from 1·18 of chloride of sodium) in 100 parts, there would be a supply of potass equal to fifteen crops of barley, and of soda equal to forty-five crops.

---

* Thus we perceive that a series of ten successive crops of turnips had added more organic matter to the soil than it had abstracted. See Boussingault's late work, chap. vii. on the Rotation of Crops.

Here also we have reason to believe, that the soil of the experimental garden was richer than that upon which our calculations are founded, so that the falling-off of the crop cannot be attributed to any actual deficiency either of alkali or of phosphoric acid in the soil.

The amount of magnesia in the soil was also very small, not exceeding 3·8 lbs. to the 100 square feet.

This however would have been sufficient for thirty-four crops of barley, according to the estimate given (in p. 230) of the quantity taken up by the crop in ten years.

When, however, we proceed to inquire into the quantity of these ingredients, which are at the particular moment in a condition to be taken up by the spongioles of the roots, we find the case very different.

I have already pointed out, that, with a view of imitating nature as nearly as possible, water impregnated with carbonic acid is a preferable solvent to muriatic acid, since it may be presumed, that what is not extracted from the soil by a sufficiently large amount of the former, is not in a condition to be readily assimilated by the plants that grow in it.

I therefore took sifted portions, each weighing 5 lbs., of the soil, from the part of the garden contiguous to the scene of my experiments, as well as from several of the plots which had grown either the same or different crops during ten years without the addition of manure, and having introduced them into earthen pots, with a hole at the bottom covered over with a piece of wire gauze fine enough to prevent the earth from falling through, I added to each a known quantity of distilled water which had been saturated with carbonic acid gas.

After a certain amount of the water had passed through, generally two quarts were taken and evaporated to dryness, after which the residuum was treated, in the first place with water, which took up the alkaline salts together with a little calcareous matter, and afterwards with muriatic acid, which dissolved the rest of the lime, whether in combination with carbonic or with phosphoric acid.

Having got rid of the earthy matter from the aqueous solution by means of oxalate of ammonia, the alkalies remaining were converted into sulphates, heated and weighed, after which the nature of the alkali, combined with the sulphuric acid, was determined by the usual method.

The acid solution was then treated with ammonia, and the precipitate, when well-washed and dried, was set down as phosphate of lime, iron being rarely present, and never except in minute proportions.

The following results were obtained, by operating in this manner on the soils enumerated below, and, granting that objections may be raised against the precision of the method adopted, they at least suffice to show, that the ten years' cropping had reduced very materially the amount of matter immediately available for the purposes of vegetation, however little it appear to have trenched upon the latent resources of the soil.

Table of the quantity of alkaline sulphates and earthy phosphates extracted by means of water impregnated with carbonic acid from the soils enumerated below.

| Soil examined and treated with water. | Quantity of water added. | Quantity of alkaline sulphate obtained. | Nature of the alkali. | Quantity of alkaline sulphate per quart of water. | Quantity of alkaline sulphate in 1 lb. of soil. | Quantity of alkaline sulphate in 100 square feet (24,600 lbs.) of the soil. | Quantity of earthy phosphate taken up. | Quantity of earthy phosphate per quart of water. | Quantity of earthy sulphate per lb. of soil. | Quantity of earthy phosphate in 100 square feet of soil (24,600 lbs.). |
|---|---|---|---|---|---|---|---|---|---|---|
| | qts. | gr. | | gr. | gr. | gr. | gr. | gr. | gr. | gr. |
| From the contiguous garden, first time .... | 2 | 5·2 | Potass. | 2·6 | ........ | .......... | 0·7 | 0·35 | | |
| From the contiguous garden, second time .. | 2 | 7·8 | Potass. | 3·9 | ........ | ......... | 0·7 | 0·35 | | |
| From the contiguous garden, third time .... | 1 | 3·4 | Potass. | 1·7 | ........ | .......... | 0·05 | 0·05 | 0·29 | 7134 |
| From the contiguous garden, fourth time .. | 1 | 2·6 | Potass. | 1·3 | 3·4 | 83640 | | | | |
| From the permanent bed of Barley........ | 2 | 0·6 | Soda. | 0·30 | 0·12 | 2950 | 0·30 | 0·15 | 0·06 | 1470 |
| From the permanent bed of Potatoes ...... | 2 | 0·7 | Soda. | 0·35 | 0·07 | 1700 | 0·25 | 0·125 | 0·05 | 1200 |
| From the permanent bed of Hemp ........ | 2 | 0·6 | Soda. | 0·30 | 0·12 | 2950 | Scarcely appreciable. | | | 1470 |
| From the permanent bed of Flax.......... | 2 | 0·5 | Soda. | 0·25 | 0·10 | 2450 | Scarcely appreciable. | | | 2940 |
| From the permanent bed of Turnips ...... | 2 | 0·6 | Soda chiefly. | 0·30 | 0·12 | 2950 | 0·30 | 0·15 | 0·06 | 3180 |
| From the permanent bed of Beans ........ | 2 | 0·5 | Soda. | 0·25 | 0·10 | 2450 | 0·60 | 0·30 | 0·12 | 4900 |
| From the shifting bed of Barley .......... | 2 | 0·7 | Soda chiefly. | 0·37 | 0·07 | 1700 | 0·065 | 0·0325 | 0·013 | 3420 |
| From the shifting bed of Potatoes ........ | 2 | 1·0 | Soda chiefly. | 0·50 | 0·20 | 4900 | 0·100 | 0·050 | 0·020 | 4900 |
| From the shifting bed of Hemp .......... | 2 | 1·0 | Soda chiefly. | 0·50 | 0·20 | 4900 | Scarcely appreciable. | | | |
| From the shifting bed of Flax............ | 2 | 0·3 | Soda chiefly. | 0·15 | 0·06 | 1470 | 0·7 | 0·35 | 0·14 | 3420 |
| From the shifting bed of Turnips ........ | 2 | 3·6 | Potass. | 1·8 | 0·72 | 17700 | 0·9 | 0·45 | 0·18 | 4410 |
| From the shifting bed of Beans .......... | 2 | 1·0 | Soda. | 0·50 | 0·20 | 4900 | 0·30 | 0·15 | 0·06 | 1470 |

Thus it is seen, that whilst the entire quantity of phosphate present in 100 square feet of the garden soil amounted to 43911 grains, or exceeded 6 lbs., and that of alkali (including both potass and soda) to 233,700 grains, exceeding 33 lbs., all that could be extracted from the same quantity of soil by water was, 7134 grains of phosphate, and an amount of alkali sufficient to produce 83,640 grains of sulphate.

It appears, moreover, that, in the soils which had been drawn upon for ten years, either by the same crop or by a succession of different ones, without the application of manure, whilst the actual amount of phosphate and of alkali was fully as great as in the other parts of the garden, the quantities extracted by water were many times less; and although it need not be supposed, that what had been withdrawn by two quarts of water constituted the whole amount of these substances which was available at the time for the purposes of vegetation, yet it seems probable, that the facility with which the above ingredients were supplied to the plants, would bear some relation to the quantities taken up by the same amount of water from the different soils.

Since, therefore, the amount of phosphates and of alkalies extracted by two quarts of water in these cases falls considerably short of the quantities of those ingredients required for an average crop of barley, such as that produced for ten years in succession in the same soil, it may be fairly concluded, that the deficiency in the produce arose in part from a less ready supply of these constituents being provided, than would have been the case in soil newly broken up, or recently manured, where, although the absolute amount of nutritious principles may not be very different, the proportion of them in a state directly applicable to the uses of the plant will be much greater.

This hypothesis however seems to me only to afford a partial explanation of the problem before us; for repeated instances occur in this paper, of two soils presenting no apparent difference in the condition of their ingredients as to solubility, and in other respects alike, which nevertheless have varied very materially in the amount and quality of their produce, according as the crop has been a permanent or a shifting one; so that in these instances, the crop had extracted different quantities of phosphates and of alkalies from two soils, both of which were capable of supplying them with these principles, with equal readiness, and in equal abundance.

This circumstance might seem to favour the idea, that the quantity and condition of the organic matter present in the soil may exercise some control over the development of the crop.

Upon the whole, then, it must, I think, be admitted, on the one hand, that the quantity of inorganic matter brought into a soluble condition would, other things remaining the same, be more considerable in proportion to the activity with which the processes of vegetation are carried on, inasmuch as those operations which result from the vitality of the plant, would facilitate that introduction of air and water into the body of the soil, by which a fresh portion of the above ingredients might be brought into a more soluble condition—owing to the separation of the clods of earth, caused by the fibres of the roots insinuating themselves amongst them—owing to water impregnated with carbonic acid, excreted by the extremities of the roots, which may exert its solvent power upon the principles contained in the soil—and owing to an imbibition, by the plants themselves, of the water surrounding them, which would cause a general movement and circulation in the fluid contained in all the portions of the soil contiguous.

On the other hand, it would seem, that a due supply of these necessary ingredients, already prepared and available for their purposes, would itself be likely to favour the development of the parts of the vegetable, and thus to cause a larger portion of such substances to be extracted from the earth, by the more vigorous action excited within the secreting organs themselves.

These effects are so connected together, that it is difficult to pronounce which of them deserves to rank as the first link in the series.

The only inferences, therefore, I could venture at present to deduce from the facts which I have laid before the Society, are as follows:—

1st. That it is quite consistent with the general tenor of the preceding facts and observations, to maintain with BOUSSINGAULT, that the falling-off of a crop is dependent upon a deficiency of organic matter proper to promote the nutrition of the plants, as well as upon a failure of its inorganic principles; not indeed that the organic matter enters, as such, into the constitution of the vegetable, but that by its decomposition it furnishes it with a more abundant supply of carbonic acid and ammonia, which supply accelerates the development of its parts, and thus at once enables it to extract more inorganic matter from the soil, and enables the soil to supply it more copiously with the principles it requires.

Hence, perhaps, in part, the advantage of intercalating the Leguminosæ and other fallow crops, which generate a larger amount of organic matter than the Cerealia, and which thus serve to enrich the soil by what they leave behind them.

2ndly. That it by no means follows, because a soil is benefited by manuring, even though that manure may, as in the case of bones, guano, &c., derive its efficacy from the phosphates it supplies, that the soil is therefore destitute of the ingredient in question, since it may happen, that it possesses abundance of it in a dormant, though not in an immediately available condition.

In these cases, in which the agriculturist has been assured by the results of actual analysis, that there is no real dearth of the principles essential to his crops in the soil which he is cultivating, but where he has ascertained, either by the chemical mode pointed out, or by an experience of the good effects brought about by manures, that the principles in question are not in a state to become immediately applicable to the purposes of vegetation, three courses appear to be open to him:—

1st. To apply a sufficient quantity of the same materials in a state in which they can be absorbed by the plants without delay; 2ndly, to allow the ground to remain fallow, by which expedient time is allowed for a further decomposition of its materials, and for a renewed extrication of its useful ingredients, to take place; 3rdly, to produce by the various methods in daily use, such a stirring and pulverization of the ground, as may admit of a more thorough admission of air and moisture, and consequently accelerate the process of disintegration in a greater degree than would take place under natural circumstances.

Examples will occur to every one of the successful adoption of each of these three practices: of the first, in the ordinary process of manuring, and especially in the beneficial consequences resulting from the use of bones in the exhausted pastures of Cheshire and other similar localities; of the second, in the system so general in the early stages of agriculture, of allowing land to remain at rest for a certain period with a view of restoring to it its exhausted powers,—a method which would be absurd, if the alkalies, phosphates, and other of the more scanty ingredients were absolutely deficient, but which would be likely to prove efficient, if they were only locked up within the recesses of the soil, and required time to render them active; of the third, in the practice resorted to by JETHRO TULL, who boasted that he could realize an abundant crop year after year without manure, provided the ground were only stirred and broken up sufficiently,—a statement which seems confirmed, by some of the results of spade husbandry, and in a certain degree by those detailed in this paper, with respect to the permanent crops which are herein mentioned as having been made the subject of experiment.

The choice between the above three methods will of course be determined in each instance by a balance of economy, and although in general this latter consideration will incline the farmer to prefer the ordinary method of manuring, either to the sacrifice of a year's produce, as in the second method, or to the expenditure of labour required to put into practice the third, still there may be cases where it might better answer his purpose to resort to one or other of them, either as being more advantageous in itself, or more suitable to the circumstances of the case.

At any rate it may be important for him to be assured, that at the very time he is ransacking the most distant quarters of the globe for certain of the mineral ingredients required for his crops, he has lying beneath his feet in many instances an almost inexhaustible supply of the very same.

For there seems no reason to doubt, that the whole mass of rock, which constitutes the subsoil in the secondary and tertiary districts of this country, is as rich in phosphates and in alkalies, as the vegetable mould derived from its decomposition; and although the soil, in which the experiments in my garden were conducted, possessed a depth nearly three times as great as the average of those in which farm produce is generally raised, yet on the other hand, the amount of phosphates and of alkaline ingredients reported to be present in them, appears in many instances greater than that determined in the case before us.

Thus Dr. URE* gives an analysis of a soil in the parish of Hornchurch, Essex, which contained four grains of phosphate of lime in 1000 grains, whereas ours scarcely exceeded one-fourth of a grain in the same quantity; and if the former be regarded as an exceptional case, I might refer to **Sprengel**, who states, that the per-centage of phosphoric acid in the soils he analysed varied from 0·024 to 0·367; and of the subsoil from about 0·007 to 0·2.

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* Journal of the Royal Agricultural Society.

I detected many years ago phosphate of lime in several secondary limestones chiefly from the oolitic formation, and Mr. **Schweitzer** of Brighton has determined the proportion of that ingredient in the chalk near Brighton, to be not less than one grain in the 1000. We need not therefore resort to South America for bones, if means could be found for extracting this ingredient economically from the rocks of our own country.

3rdly. These facts place in rather a new light, although one, it is conceived, not less striking than before, the importance of taking care of the various excrementitious matters at our disposal, whether proceeding from animal or from vegetable sources.

Such substances indeed contain the products, which nature has, with so large a consumption of time, and by such a number of complicated operations, elaborated from the raw material contained in the soil, and has at length brought into the condition, in which they are most soluble, and therefore best fitted to be assimilated by the organs of plants.

To waste them, is therefore to undo, what has been expressly prepared for our use by a beautiful system of contrivances, and to place ourselves under the necessity of performing, by an expenditure of our own labour and capital, those very processes, which nature had already accomplished for us, without cost, by the aid of those animate or inanimate agents which she has at her disposal.

4thly. The analyses above reported may suggest caution as to the inferences which some might be disposed to deduce from certain researches lately announced, with respect to the power which a plant possesses of substituting one alkali, or one earth, for another, in the processes of vegetation.

This substitution indeed, however brought about, is a fact which hardly admits of being questioned, supported as it is by the testimony of men so eminent as **Saussure** and as **Liebig**, and indeed many of the analyses detailed in this paper might be appealed to in corroboration of its truth.

Thus we find, that whilst the amount of bases agreed pretty nearly in the three crops of the same plant which had been analysed, the proportions between them often varied considerably. This is particularly seen in the case of the lime and magnesia, the deficiency in one of these earths being often made up by an excess in the other.

In like manner a deficiency of potass is found to be compensated by an increased amount of soda, and the same remark seems to apply to the acids.

Still we have not as yet sufficient data for determining to what extent this exchange of the usual ingredient for another can take place; whether indeed the same organ, or the same proximate principle belonging to the plant, may admit at all of this change in its constitution taking place; or if it can, in what degree the presence of this new principle may affect the healthy development of the vegetable.

By turning to the Table which states the relative quantities of alkaline ingredients extracted from the different soils by water impregnated with carbonic acid, it will be seen, that in most of these the amount of soda predominated over that of potass, and yet the latter alkali was principally found in their ashes, an indication at least of some superior adaptation of potass to soda for the organization of plants*.

Again, it is remarkable, that whilst in several of the soils soda appeared to exist in the form of a carbonate (since the quantity of chlorine was so small that only a minute trace of it was discoverable in them), in many of the ashes of the plants, only as much soda was detected as would contain sodium equivalent to the chlorine present.

Hence it would seem to follow, that common salt, when it acts beneficially upon land, does not assist the crop by virtue of the alkali it imparts to it, but in some other way, and that it is still questionable, at least in the case of terrestrial species, whether plants have the power of decomposing chloride of sodium, and of separating its chlorine.

Lastly, the analyses contained in this paper may be of use at the present moment, by contributing to show, how much still remains to be done, before we can flatter ourselves at having attained any sure knowledge of the normal constitution of plants, and of the range of variation of which under natural circumstances it is susceptible. At a time when certain enlightened members of the Royal Agricultural Society have prevailed upon that great Body, to devote a portion of their funds to the prosecution of the chemical analysis of the ashes of vegetables, whatever tends to render more palpable the importance of such an investigation, may be of service, in aiding their meritorious efforts, to give a more scientific direction to the inquiries which such associations are intended to promote, and in vindicating the utility of the course which they have in this instance adopted.

Now the facts and observations detailed in the present paper contribute in two respects towards this object, viz. by showing that the composition of the most commonly cultivated plants is still open to much uncertainty; and 2ndly, by pointing out in what way an exact knowledge of their inorganic ingredients might aid us towards the solution of many important practical questions.

I hope, it will not be attributed to any blindness on my part to the deficiencies and imperfections which exist in this paper, if I remark, that an investigation of a similar kind to the one herein detailed, if carried out on a more adequate scale, undertaken on ground more carefully selected, conducted with a more vigilant attention to all the minute circumstances which might influence the result, and accompanied by a regular series of analyses, both of the soil and of the crops, during the whole period of their continuance, would be of essential service in clearing up many points which yet remain open to investigation in agricultural science.

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* This is also shown very strikingly in a paper on the analysis of Fuci, read to the British Association at Cambridge, by Mr. SCHWEITZER, in June 1845.

My Memoir may serve also as a kind of illustration of that method of Scientific Book-keeping, which I proposed some time ago, at once as an useful exercise for the agricultural student, and as a means of introducing greater precision in the conduct of our experiments on this subject, and which I am therefore happy in having this opportunity of rendering more generally known.

## VIII. *An Account of the Artificial Formation of a Vegeto-Alkali.*

*By* GEORGE FOWNES, *Ph. D., F.R.S., Chemical Lecturer in the Middlesex Hospital Medical School. Communicated by* THOMAS GRAHAM, *Esq., F.R.S., &c.*

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A FEW months ago Mr. MORSON very kindly put into my hands, for examination, a quantity of dark-coloured, viscid oil, amounting to six or seven ounces, which was said to have been produced by the action of sulphuric acid upon bran. The tarry appearance of the oil was evidently the result of oxidation, for the bottle in which it had been preserved during a period of five years was very imperfectly closed, while a second and smaller portion, which had been kept in a stoppered bottle the same length of time, although dark in colour, was perfectly thin and fluid.

A portion of the oil was introduced into a retort, together with a quantity of water, and the whole submitted to distillation; water, accompanied by a heavy, pale-yellow volatile oil, came over. At the close of the process the retort was found to contain a solid, pitchy residue, insoluble in water, but dissolved in great measure by caustic potash, and again precipitable by the addition of an acid.

The distilled oil, separated by a funnel from the water under which it rested, after having been left a few days in contact with fused chloride of calcium, was distilled alone in a small retort fitted with a thermometer, the bulb of which dipped into the liquid. A little water came over at first with the oil, but this quickly ceased to appear, and then the temperature of ebullition remained quite constant to the close of the distillation, which was conducted nearly to dryness. It was inferred from this experiment that the oil was a single substance, and not a mixture of two or more different bodies.

The water which came over with the oil in the first distillation contained a very considerable quantity of that substance in a state of solution; it was strongly acid besides, from the presence of formic acid.

The purified oil was next submitted to analysis in the usual manner, by combustion with oxide of copper. The following were the results:—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Oil employed . . . . | 5·73 grs. | 7·79 grs. | 5·547 grs. |
| Carbonic acid produced | 13·18 grs. | 17·74 grs. | 12·64 grs. |
| Water produced . . . | 2·27 grs. | 2·96 grs. | 2·12 grs. |

Hence the composition in 100 parts*, nitrogen being altogether absent,—

---

* The equivalent of carbon is taken throughout =6.

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon . . . . . . . | 62·73 grs. | 62·11 grs. | 62·14 grs. |
| Hydrogen . . . . . . | 4·40 grs. | 4·22 grs. | 4·24 grs. |
| Oxygen . . . . . . . | 32·87 grs. | 33·67 grs. | 33·62 grs. |
| | 100·00 | 100·00 | 100·00 |

The formula $C_{15} H_6 O_6$, calculated to 100 parts, gives numbers almost coincident with the above, viz.—

| | |
|---|---|
| Carbon . . . . . | 62·50 |
| Hydrogen . . . | 4·17 |
| Oxygen . . . . | 33·33 |
| | 100·00 |

The following is a summary of the chief properties of the oil:—

When free from water and freshly rectified, it is nearly colourless, but after a few hours acquires a brownish tint, which eventually deepens almost to blackness; when in contact with water, or when not purposely rendered anhydrous, it seems less subject to change, and merely assumes a yellow colour. Its odour resembles that of a mixture of bitter almond oil, and oil of cassia, but has less fragrancy. The specific gravity of this substance at 60° is 1·168; it boils at 323° FAHR., and distils at that temperature without alteration. Cold water dissolves the oil in question to a very large extent; by distillation, and fractioning the products, it can be again separated. In alcohol it dissolves with perfect facility. Concentrated sulphuric acid dissolves it in the cold with magnificent purple colour; the solution is decomposed by water, with separation of the oil. If heated with the acid, it is charred and destroyed with evolution of sulphurous acid. Strong hydrochloric acid behaves in a very similar manner. Nitric acid, by the aid of a little heat, attacks the oil with prodigious violence, evolving copious red fumes, and generating oxalic acid, which appears to be the only product.

Solution of caustic potash, in the cold, slowly dissolves the oil, forming a deep brown liquid, from which acids precipitate resinous matter; by the aid of heat, the same change ensues very rapidly. Metallic potassium was found to be slowly acted upon by the cold oil, but on slightly elevating the temperature, an explosion took place, attended by a voluminous flame and a large deposit of soot, my hand being at the same time severely burned by a portion of the projected potassium.

The most remarkable and characteristic reaction of this substance, however, is with ammonia. When placed in contact with five or six times its bulk of ordinary *liquor ammoniæ*, and left some hours, it is gradually, but in the end completely converted into a solid, yellowish-white, and somewhat crystalline mass, which is very bulky, and perfectly insoluble in cold water. It may be easily collected on a filter, drained from the ammoniacal mother-liquor, and dried *in vacuo* over a surface of oil of vitriol. This substance appears to be the only product of the action of ammonia on the volatile oil.

Portions of the new body, prepared in the manner above stated, and very carefully dried over sulphuric acid, gave the following results on analysis by combustion with oxide of copper. The proportion of nitrogen was determined by the excellent method of MM. Will and Varrentrapp.

| | (1) | (2.) | (3.) |
|---|---|---|---|
| Substance employed . . . | 7·94 grs. | 6·37 grs. | 4·195 grs. |
| Carbonic acid produced . | 19·34 grs. | 15·57 grs. | 10·24 grs. |
| Water produced . . . . | 3·24 grs. | 2·59 grs. | 1·69 grs. |

Hence, in 100 parts—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon . . . . . . . . | 66·55 grs. | 66·66 grs. | 66·57 grs. |
| Hydrogen . . . . . . . | 4·53 grs. | 4·52 grs. | 4·47 grs. |

Determination of nitrogen*:—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Substance employed . . . | 6·02 grs. | 4·65 grs. | 4·45 grs. |
| Platinum-salt obtained . . | 10·10 grs. | 7·62 grs. | 7·17 grs. |
| Per-centage of nitrogen . | 10·58 | 10·54 | 10·16 |

These results lead directly to the formula $C_{15}H_6NO_3$; when this is reckoned to 100 parts, it gives—

| | |
|---|---|
| Carbon . . . . . | 67·13 |
| Hydrogen . . . . | 4·47 |
| Nitrogen . . . . | 10·48 |
| Oxygen . . . . . | 17·92 |
| | 100·00 |

Hence it is clear that the solid substance is produced from the oil by the assimilation of the elements of one equivalent of ammonia, and the separation of those of three equivalents of water.

$$\begin{array}{lcl}
\left.\begin{array}{ll}\text{Oil} \;.\;.\;.\;.\;. & C_{15}H_6\quad O_6 \\ +1\text{ eq. ammonia} \;. & \quad\; H_3N\end{array}\right\} & = & \left\{\begin{array}{ll}\text{solid} \;.\;.\;.\;.\;. & C_{15}H_6NO_3 \\ \text{3 eq. water} \;.\;.\;. & \quad H_3\quad O_3\end{array}\right. \\
\hline
\qquad\qquad\qquad\quad C_{15}H_9NO_6 & & \qquad\qquad\qquad\quad C_{15}H_9NO_6
\end{array}$$

The new substance belongs in fact to the class of the *amides*, which it resembles in many important particulars, as will be more apparent in the sequel.

In the year 1841 Dr. Stenhouse[†] published an interesting paper on a peculiar oily matter, first noticed by Doebbereiner, which occasionally appears in very small quantity, in the preparation of artificial formic acid from sugar or starch, oxide of manganese, and dilute sulphuric acid, and to which he gave the name of *artificial oil of ants*. Dr. Stenhouse, in the investigation above referred to, succeeded in pre-

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[*] It may not be amiss perhaps to mention, that in the method adopted the organic substance is strongly heated in a hard glass tube with a mixture of hydrate of soda and quicklime. The whole of the nitrogen issues thence in the form of ammonia, and being condensed into hydrochloric acid, is afterwards converted into chloride of platinum and ammonium, from the weight of which that of the nitrogen is easily calculated.

[†] Philosophical Magazine for February 1841; also Annalen der Chemie und Pharmacie, xxxv. p. 301.

paring this substance at will, and in sufficient quantity to serve the purposes of experiment; he found it composed of carbon, hydrogen and oxygen, and, what appeared very extraordinary in such a body, the two latter elements were in the proportions to form water. The analytical results, reckoned to 100 parts, were as follows:—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon . . . . . | 62·59 | 61·87 | 62·55 |
| Hydrogen . . . | 4·37 | 4·37 | 4·46 |
| Oxygen . . . . . | 33·04 | 33·76 | 32·99 |
| | 100·00 | 100·00 | 100·00 |

These numbers agree very closely with those furnished by the assigned empirical formula $C_5 H_2 O_2$.

There could be but little doubt that the oil upon which I had been experimenting was identical with the substance above described; its properties agreed on the whole pretty well with those assigned by Dr. STENHOUSE to his interesting product, with the exception of its extraordinary behaviour with ammonia, which seems to have escaped notice, probably from time being required for the production of the *amide*. To complete the identification, therefore, a small portion of oil was prepared, the process described and recommended being closely followed. 2 lbs. of oatmeal, 2 lbs. of water, and 1 lb. of oil of vitriol, were well-mixed in a small copper still, and heated until the pasty mass became thin and fluid from the conversion of the starch into dextrine; the head was then applied and luted down, and distillation commenced. As soon as sulphurous acid began to appear, an additional lb. of water was introduced, and the distillation continued until that gas began to escape in large quantity. The liquid which came over was then rectified to one-half, the product neutralized with hydrate of lime to fix the sulphurous and formic acids, and again distilled, the first third only being collected. A small quantity of heavy yellow oil was thus procured, and an additional portion obtained by again subjecting the watery liquid to distillation. So far as could be seen, this oil corresponded in every particular with that examined by myself; when put into solution of ammonia it formed in a few hours the characteristic yellowish compound, identical in composition and properties with that already described.

The nature of the oil so far elucidated, it will be proper to return to the subject of the *amide*, or ammonia-compound, the latter term being however hardly applicable. The mode of preparation of this substance has been already described; it is always produced when ammonia and the oil are brought into contact. It is very pale yellow, approaching to white, and nearly inodorous when dry and pure; in cold water it is insoluble; alcohol and ether, on the other hand, dissolve it freely. It may be obtained in tufts of small, short, acicular crystals, by allowing a hot, saturated alcoholic solution to cool; or whiter and purer, by adding ammonia to a saturated aqueous solution of the oil, and allowing the mixture to stand several days. In chemical characters this amide much resembles the *hydrobenzamide* of M. LAURENT, obtained by putting pure bitter almond oil into solution of ammonia. It is slowly decomposed by boiling water, and even by boiling alcohol, into free ammonia and volatile oil, and very slowly suffers the same kind of decomposition by moisture at the common temperature of the air. When heated, it melts, inflames, and burns with a smoky light, leaving a small deposit of charcoal. Acids decompose it immediately; a salt of ammonia is produced, and the original oil set free.

The action of alkalies on this substance is very remarkable, and well deserves attention. When boiled with a large quantity of dilute solution of caustic potash, it dissolves without the *least evolution of ammonia*, and the liquid deposits, on cooling, small, white, silky needles of a second new substance, having the *same composition* as the amide itself, but all the properties of a stable and exceedingly energetic organic base, possessing alkalinity, and having the power of forming with acids an extensive series of well-defined, and for the most part, crystallizable salts of great beauty.

Portions of the new salt-base, prepared at different operations with the greatest care, were submitted to ultimate analysis by burning with oxide of copper as before, the substance being dried *in vacuo* over a surface of oil of vitriol; the following results were obtained:—

| | (1.) | (2.) | (3.)* |
|---|---|---|---|
| Substance employed . . | 2·668 grs. | 3·985 grs. | 3·698 grs. |
| Carbonic acid produced . | 6·53 grs. | 9·74 grs. | 9·06 grs. |
| Water produced . . . | 1·12 grs. | 1·63 grs. | 1·51 grs. |

Hence, in 100 parts,—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon. . . . | 66·75 | 66·66 | 66·82 |
| Hydrogen . . | 4·66 | 4·54 | 4·53 |

Estimation of nitrogen:—

| | (1.) | (2.) |
|---|---|---|
| Substance employed. . | 3·79 grs. | 3·75 grs. |
| Platinum salt produced | 6·12 grs. | 6·11 grs. |
| Per-centage of nitrogen | 10·18 | 10·28 |

The isomerism of the two substances is seen to be most complete; the numbers obtained by analysis absolutely coincide: and yet how discrepant their properties!

I am inclined to think that the nature of the isomeric change which the amide undergoes in presence of the alkali consists simply in a duplication of its elements; at least, this is the simplest view that can be taken. It is besides the only product. It will be seen from analyses of the salts formed by this substance, that the proportion of matter required to form a perfectly neutral compound with an acid, organic or inorganic, is expressed by the formula $C_{30}H_{12}N_2O_6$, which is the double of the *amide* $C_{15}H_6NO_3$. But then, as the constitution of this latter substance must be to some extent uncertain, since that of the oil is also unknown, and the *amide* forms no combinations, the above view must remain merely conjectural.

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* This specimen was prepared from the oxalate by precipitation by ammonia.

I pass now to a description of the properties of the new salt-base, of its principal salts yet studied, and of the best method of preparation on a considerable scale.

The substance itself crystallizes from boiling water in fine, soft, white, silky needles, much resembling those of cafeine, quite permanent in the air, and even in the dry vacuum. It has but little taste, although its salts are very bitter; they are far less so however than those of morphia, or of the bark-alkalies. It is inodorous. At a temperature rather below the boiling-point of water it melts to a heavy, nearly colourless, oily liquid, which on cooling assumes at first the consistence of a soft resin, but eventually becomes brittle and crystalline. When strongly heated in the air, the new substance inflames, burns with a red and smoky light, and leaves but very little charcoal. It is soluble in about 135 parts of boiling water, but after cooling, scarcely a trace remains dissolved. Alcohol and ether in the cold dissolve it with the utmost facility; the alcoholic solution deposits, on spontaneous evaporation, exceedingly brilliant silky crystals; the liquid has a great tendency to creep up the sides of the vessel. The alkaline reaction to test-paper, when dissolved in hot water or alcohol, is exceedingly strong and well-marked. Dilute acids dissolve this substance with the utmost ease, becoming thereby completely neutralized, unless employed in excess; from these combinations the base is precipitated in an unchanged state, by the addition of ammonia or of a fixed alkali. A salt of the new base gives no precipitate with solutions of peroxide of iron, oxide of copper or silver, lime or baryta; the hydrochlorate forms with corrosive sublimate, a white, and with chloride of platinum, a bright yellow, double salt. What is rather remarkable, it is not precipitated to any extent by tincture of galls. So powerful are the basic properties of this alkaloid, that when boiled with a solution of sal-ammoniac, it decomposes that salt with evolution of ammonia and formation of a hydrochlorate.

The salts formed by this curious body are exceedingly numerous, and would in all probability well repay a more extended investigation; the few yet examined are the following:—

*Hydrochlorate.*—This is easily prepared by dissolving the alkaloid in dilute, warm hydrochloric acid, to saturation. The salt, which is perfectly neutral to test-paper, forms tufts of fine, silky, acicular crystals, like those of hydrochlorate of morphia. It is very soluble in pure water, but far less so in an excess of hydrochloric acid. The crystals retain their brilliancy when dried *in vacuo* over sulphuric acid. An analysis of this salt gave the following results:—

| (Carbon and hydrogen.) | (1.) | (2.) | (3.) |
|---|---|---|---|
| Salt employed . . . . . | 5·855 grs. | 5·435 grs. | 6·115 grs. |
| Carbonic acid produced . . | 12· grs. | 11·12 grs. | 12·55 grs. |
| Water produced . . . . . | 2·49 grs. | 2·27 grs. | 2·56 grs. |

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon . . . . | 55·89 | 55·62 | 55·97 |
| Hydrogen . . . . | 4·72 | 4·64 | 4·65 |

6·027 grs. salt gave of chloride of silver 2·65 grs. = 10·67 per cent. chlorine.

6·68 grs. salt gave of chloride of silver 2·92 grs. = 10·60 per cent. chlorine.

6·147 grs. salt gave of double chloride of platinum and ammonium 8·24 grs. = 8·45 per cent. nitrogen.

The formula $C_{30}\,H_{12}\,N_2\,O_6$, HCl+2HO, reckoned to 100 parts, gives numbers closely agreeing with the preceding; viz.—

| | |
|---|---|
| Carbon | 55·81 |
| Hydrogen | 4·65 |
| Nitrogen | 8·72 |
| Chlorine | 10·98 |
| Oxygen | 19·84 |
| | 100·00 |

When a solution of the hydrochlorate of the new base is mixed with one of bichloride of platinum, an insoluble, or sparingly-soluble, bright yellow, crystalline precipitate falls, which is a compound of the two bodies. It is blackened and decomposed by boiling. When heated in the dry state, it melts, blackens, and swells up to a prodigious extent, evolving fumes of sal-ammoniac; the incineration of the charcoal is slow and difficult. Examined by analysis, the double salt gave the following results:—

| | |
|---|---|
| Salt employed | 7·28 grs. |
| Carbonic acid produced | 10·16 grs. |
| Water produced | 1·97 grs. |

In 100 parts,—

| | |
|---|---|
| Carbon | 38·06 |
| Hydrogen | 3· |

16·43 grs. salt gave of metallic platinum 3·36 grs., or 20·45 per cent.

The formula $C_{30}\,H_{12}\,N_2\,O_6$, HCl+$PtCl_2$, calculated to 100 parts, gives—

| | |
|---|---|
| Carbon | 37·97 |
| Hydrogen | 2·74 |
| Platinum | 20·90 |

*Nitrate.*—This is a very beautiful salt; it forms hard, transparent, colourless, and very brilliant crystals, whose form yet remains to be determined. It is freely soluble in pure water, but very sparingly soluble in excess of nitric acid. The crystals effloresce and become opake in a dry atmosphere. In this state they contain $C_{30}\,H_{12}\,N_2\,O_6$, $NO_5$+HO, as shown by the result of an analysis given below.

| | |
|---|---|
| Nitrate employed | 5·62 grs. |
| Carbonic acid produced | 11·19 grs. |
| Water produced | 2·02 grs. |

or, in 100 parts,—

| | |
|---|---|
| Carbon | 54·30 |
| Hydrogen | 3·99 |

The theoretical quantities are—

| | |
|---|---|
| Carbon | 54·35 |
| Hydrogen | 3·93 |

*Oxalates.*—The neutral oxalate is a very soluble salt, crystallizing, when the solution is sufficiently concentrated, in tufts of fine needles, like the hydrochlorate. The binoxalate is very sparingly soluble in the cold, and crystallizes remarkably well when a hot saturated solution is left slowly to cool. It forms transparent plates, like those of oxalate of urea, which have a strong acid reaction when dissolved, and retain their lustre in the dry vacuum. This substance gave on analysis the results stated below, leading to the formula $C_{30}H_{12}N_2O_6$, $2C_2O_3+2HO$.

| | |
|---|---|
| Salt employed | 4·808 grs. |
| Carbonic acid produced | 10·05 grs. |
| Water produced | 1·76 grs. |

4·85 grs. salt gave of double chloride of platinum and ammonium 5·95 grs., or 7·74 per cent. nitrogen.

Hence, in 100 parts,—

| | |
|---|---|
| Carbon | 57·01 |
| Hydrogen | 4·06 |
| Nitrogen | 7·74 |
| Oxygen | 31·19 |
| | 100·00 |

The theoretical numbers are—

| | |
|---|---|
| Carbon | 56·96 |
| Hydrogen | 3·91 |
| Nitrogen | 7·85 |
| Oxygen | 31·28 |
| | 100·00 |

The *acetate* is very soluble, and apparently uncrystallizable, or at least crystallizable with great difficulty.

The following is an excellent and easy method of preparing the vegeto-alkali in a state of purity and whiteness. The *amide*, dried in the air, or better, over oil of vitriol in the vacuum of the air-pump, is thrown into a large quantity of boiling-hot dilute solution of caustic potash contained in a capacious glass flask placed over a lamp or chauffer. After ten or fifteen minutes' ebullition the change is complete, the great bulk of the new substance appearing in the form of a heavy, yellowish oil, which, on the removal of the vessel from the fire, collects at the bottom of the flask, and on cooling, solidifies, while that which had been dissolved by the liquid crystallizes out. When perfectly cold, the whole is thrown upon a cloth filter, slightly washed with cold water, and then dissolved in a large quantity of dilute boiling solution of oxalic acid, the acid being kept in considerable excess. The liquid, filtered hot, deposits on cooling a large crop of crystals of the acid oxalate of the base, dark-coloured, however, and impure. The salt may then be collected on a cloth filter, slightly washed and pressed, redissolved in boiling water, and heated for a few minutes with a little good animal charcoal, deprived of its earthy phosphates, &c., by washing with hydrochloric acid. The filtered solution now deposits the acid oxalate in a state of perfect whiteness and purity; from the pure salt the alkali may be obtained in crystals by solution in a large quantity of boiling water, addition of excess of ammonia, and rapid filtration at a high temperature. The crystals which form on cooling require of course washing with distilled water until all the ammoniacal and other salts are removed, and a portion of the alkaloid taken from the filter is found to leave no residue when completely burned on platinum.

I am in great doubt as to the most appropriate names to be bestowed on these curious bodies, and this doubt will remain until more is known respecting the real origin of the oil. This substance has no apparent connection with formic acid, except the accidental one of contemporaneous production. It is allied in *constitution* to the sugar and starch series, inasmuch as it contains oxygen and hydrogen in the proportions to form water, and in *properties* to bitter almond oil and the essential oils in general. So far as my own experiments go, it seems to be produced most freely and in greatest abundance from bran, 1 lb. of that substance distilled with half its weight of sulphuric acid and 3 lbs. of water having yielded nearly a drachm of oil, while mere indistinct traces could be obtained from similar quantities of rice- and potatoe-starch. Under these circumstances, perhaps the name "Furfurol" (from *furfur*, bran, and *oleum*) might be applied provisionally, and I am informed that this is the name which was proposed by the party who several years ago prepared a considerable quantity of the oil (a portion of which came into my hands, as mentioned at the commencement of this paper), and endeavoured to discover for it economical applications.

The following, therefore, will be the provisional nomenclature:—

Oil produced by the action of sulphuric acid on bran, &c., termed "furfurol," $C_{15}H_6O_6$.

Product of the action of ammonia on furfurol, or "furfurolamide," $C_{15}H_6NO_3$.

Vegeto-alkali, "furfurine," produced by the duplication of the elements of furfurolamide, $C_{30}H_{12}N_2O_6$.

In conclusion, I beg to direct attention to the large and promising field of investigation offered by the study of the action of ammonia on the volatile oils, and on other allied bodies.

*Middlesex Hospital,*
*Jan.* 9, 1845.

### NOTE ADDED DURING THE PRINTING.

Since the preceding paper was read I have received a communication from the gentleman just referred to, Mr. WILLIAM COLEY JONES, late of Plymouth, who has directed my attention to an article in the Polytechnic Journal, April 1840, in which he has described some of the more important properties of the oil in question, and among others, its power of generating a solid compound with ammonia, which when distilled with dilute sulphuric acid reproduced the furfurol. Mr. JONES prepared furfurol on a very extensive scale from the waste "lignin," or bran, separated from wheat in the process of starch-making; the details of the method however are not given, and there are no analyses of the products. I feel no hesitation in expressing my opinion that the honour of the independent discovery of this most curious body is justly due to Mr. JONES, and it is much to be regretted that it did not receive greater publicity.

*Aug.* 12, 1845.

## IX. *On Benzoline, a new Organic Salt-base from Bitter Almond Oil.*

*By* **George Fownes**, *Esq., Ph.D., F.R.S.*

Received May 9,—Read May 29, 1845.

WHEN pure oil of bitter almonds is left some days in contact with a strong solution of ammonia, at the ordinary temperature of the air, it is slowly, but in the end completely converted into a white crystalline substance, insoluble in water, but readily soluble in hot alcohol. The solidification of the oil is complete, and there is no secondary product. This substance was examined by M. Laurent[*], who conferred upon it the name of *hydrobenzamide*, and assigned to it the formula $C_{42}H_{18}N_2$; it is generated by the union of the elements of two equivalents of ammonia with those of three equivalents of hydruret of benzoyle, and the separation of six equivalents of water.

$$\left.\begin{array}{ll}\text{3 eq. bitter almond oil .} & C_{42}H_{18}\quad O_6\\ \text{2 eq. ammonia. . . . . .} & \quad H_6N_2\end{array}\right\} = \left\{\begin{array}{ll}\text{Hydrobenzamide} & C_{42}H_{18}N_2\\ \text{6 eq. water . . .} & \quad H_6\quad O_6\end{array}\right.$$

$$C_{42}H_{24}N_2O_6 \qquad\qquad C_{42}H_{24}N_2O_6$$

Acids decompose hydrobenzamide immediately, with separation of bitter almond oil and formation of salt of ammonia; with alkalies the case is different, solution of potash, even at a boiling heat, occasioning, as remarked by M. Laurent, no perceptible change. I found however that when the boiling was prolonged for some hours, a change was induced resembling that undergone by *furfurolamide*[†] under similar circumstances. A few brownish crystalline flocks appear in the solution, and after cooling, the cake of resin-like substance is found harder and less fusible than hydrobenzamide which has been melted and left to solidify. This change is unaccompanied by any notable alteration of weight, although a faint odour of bitter almond oil is disengaged during the whole course of the ebullition. The new substance is an organic salt-base, having the same composition as hydrobenzamide itself; it might perhaps with propriety be called *benzoline*.

The salts formed by this substance are for the most part remarkable for sparing solubility, with the exception of the acetate; the hydrochlorate, the nitrate, and the sulphate are crystallizable; the last-named salt is exceedingly beautiful, crystallizing from an acid solution in colourless prisms resembling those of oxalic acid.

Precipitated by ammonia from a cold solution of the hydrochlorate or sulphate, benzoline separates in white curdy masses, which when washed and dried diminished greatly in volume; when quite dry the powder is singularly electric; if rubbed with a spatula its particles repel each other with violence, scattering the powder over the paper on which it lies. It is not sensibly soluble in water, but dissolves with great ease in alcohol and ether. A hot alcoholic solution left for some time deposits the base in brilliant transparent colourless crystals, which apparently have the form of square prisms with variously-terminated summits; the alcoholic solution is strongly alkaline to test-paper. At a temperature below 212° benzoline melts, and on cooling assumes a transparent glassy state, without any tendency to crystallization. Heated in a retort, it boils and at length entirely volatilizes, with scarcely a residue of charcoal. Ammonia is disengaged during the distillation, a highly volatile oily liquid, having the odour of benzine, collects in the receiver, and a crystalline solid matter condenses in the neck of the retort. This latter substance, which seems to be the most abundant product, has been but partially examined; it is described below under the name *pyrobenzoline*.

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[*] Ann. Chim. et Phys. 62, p. 23.

[†] See preceding paper.

The action of oxidizing agents upon benzoline is remarkable. When heated in a retort with a mixture of bichromate of potash, sulphuric acid and water, it is attacked with great energy, the mixture becomes dark green, and on distillation benzoic acid in large quantity passes over with the vapour of water. With nitric acid the same change seems to occur, but the action is not so definite and speedy. Hydrobenzamide, under similar circumstances, yields the same product, accompanied however in the first part of the distillation by a little bitter almond oil. Melted hydrate of potash appears to exert no action on benzoline, unless the temperature be excessive.

The composition of this substance and its isomerism with hydrobenzamide, are shown by the following analyses:—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Substance . . . . . . | 4·018 grs. | 4·03 grs. | 4·57 grs. |
| Carbonic acid produced . . | 12·37 grs. | 12·46 grs. | 14·14 grs. |
| Water produced . . . . | 2·21 grs. | 2·18 grs. | 2·52 grs. |

In 100 parts,—

| | (1.) | (2.) | (3.) |
|---|---|---|---|
| Carbon . . . | 83·96 | 84·32 | 84·38 |
| Hydrogen . . | 6·11 | 6·01 | 6·12 |

The nitrogen was determined by the process of MM. Will and Varrentrapp, as below:—

| | (1.) | (2.) |
|---|---|---|
| Substance. . . . . . . . | 3·88 grs. | 5·036 grs. |
| Platinum salt produced . . . | 5·57 grs. | 7·28 grs. |
| Per-centage of nitrogen . . . | 9·07 | 9·12 |

Hydrobenzamide contains by calculation in 100 parts,—

| | |
|---|---|
| Carbon | 84·56 |
| Hydrogen | 6·04 |
| Nitrogen | 9·40 |
| | 100·00 |

*Hydrochlorate.*—The hydrochlorate of benzoline is a sparingly-soluble salt even in boiling water. It crystallizes from a hot solution in small but exceedingly brilliant colourless needles, which effloresce in the dry vacuum. It has, in common with the other salts, an intensely bitter taste. The salt, deprived of its water of crystallization, gave the following analytical results:—

| | (1.) | (2.) |
|---|---|---|
| Substance | 4·25 grs. | 4·458 grs. |
| Carbonic acid produced | 11·71 grs. | 12·30 grs. |
| Water produced | 2·21 grs. | 2·32 grs. |

In 100 parts,—

| | (1.) | (2.) |
|---|---|---|
| Carbon | 75·14 | 75·25 |
| Hydrogen | 5·77 | 5·78 |

Estimation of nitrogen and chlorine:—

| | |
|---|---|
| Substance | 4·16 grs. |
| Platinum salt produced | 5·17 grs. |
| Per-centage of nitrogen | 7·83 |

| | (1.) | (2.) |
|---|---|---|
| Substance | 5·838 grs. | 4·218 grs. |
| Chloride of silver produced | 2·32 grs. | 1·76 grs. |
| Per-centage of chlorine | 9·64 | 10·12 |

The formula $C_{42} H_{18} N_2, H Cl$ gives in 100 parts,—

| | |
|---|---|
| Carbon | 75·33 |
| Hydrogen | 5·68 |
| Nitrogen | 8·41 |
| Chlorine | 10·58 |
| | 100·00 |

The crystallized salt was found to lose by efflorescence 2·4 per cent. of water, corresponding very nearly to one equivalent.

The hydrochlorate of benzoline forms with bichloride of platinum an insoluble double salt of a pale yellow colour, not further examined.

*Nitrate.*—The nitrate is even less soluble than the preceding salt; the crystals are small and have but little brilliancy; they are permanent in the dry vacuum. A portion subjected to analysis gave the following results:—

| | (1.) | (2.) |
|---|---|---|
| Substance . . . . . | 4·112 grs. | 4·27 grs. |
| Carbonic acid produced | 10·51 grs. | 10·91 grs. |
| Water produced . . . | 1·97 grs. | 2·03 grs. |

In 100 parts,—

| | (1.) | (2.) |
|---|---|---|
| Carbon . . . . . . | 69·71 | 69·68 |
| Hydrogen . . . . . | 5·32 | 5·28 |

The formula $C_{42}H_{18}N_2, NO_5+HO$, gives in 100 parts,—

| | |
|---|---|
| Carbon . . . . . | 69·77 |
| Hydrogen . . . . | 5·26 |

The *acetate* is a very soluble salt; it dries up, on evaporation, to a gummy adhesive mass, and probably crystallizes with difficulty, if at all.

*Pyrobenzoline.*—This, as before observed, is the solid product of the dry distillation of benzoline. It is pressed between folds of bibulous paper to free it as much as possible from oily matter, and then crystallized from boiling alcohol, in which it dissolves pretty freely. It is but sparingly soluble in alcohol in the cold, and apparently quite insoluble in water, dilute acids and alkalies. It is tasteless, and the alcoholic solution has little or no alkaline reaction. At a high temperature this substance fuses, and with still further increase of heat distils; it sublimes at a temperature below its boiling-point, the vapour condensing in feathery crystals like those of benzoic acid. Melted pyrobenzoline on cooling forms a mass of radiated crystals, presenting a great contrast to the glassy or resinous appearance of benzoline under similar circumstances. This substance was at first imagined to be a hydrocarbon; it contains nitrogen, however, and gave on analysis the results stated below.

| | (1.) | (2.) |
|---|---|---|
| Substance . . . . . | 4·295 grs. | 3·46 grs. |
| Carbonic acid produced | 13·42 grs. | 10·74 grs. |
| Water produced . . . | 2·08 grs. | 1·71 grs. |

Hence in 100 parts,—

| | (1.) | (2.) |
|---|---|---|
| Carbon . . . . . . | 85·21 | 84·66 |
| Hydrogen . . . . . | 5·38 | 5·49 |

Estimation of nitrogen:—

| | |
|---|---|
| Substance . . . . . . . . . | 4·15 grs. |
| Platinum salt produced . . . | 6·00 grs. |
| Per-centage of nitrogen . . . | 9·11 |

These numbers lead to the formula $C_{21} H_8 N$, which gives in 100 parts,—

| | |
|---|---|
| Carbon | 85·1 |
| Hydrogen | 5·4 |
| Nitrogen | 9·5 |
| | 100·00 |

This, which appears to be a neutral body, together with its accompanying liquid product, deserves a more extended examination.

The hope which I ventured to express in a former paper of the formation of new organic bases from the volatile oils which unite with ammonia, by subjecting their *amides* to the influence of agents, as caustic potash, capable of bringing about metamorphosis of the compound into a more stable form or forms of combination, has thus been partially fulfilled.

M. Laurent has recently announced the discovery of a new substance obtained from bitter almond oil, isomeric with hydrobenzamide, possessing basic properties, and corresponding in some other respects with benzoline; it is stated however to be volatile without decomposition, which is certainly not the case with that body. The name *amarine* was conferred upon it*. The publication of the experiments in detail will probably determine the identity or separate nature of the two substances.

* Comptes Rendus, xix. p. 353.

*Middlesex Hospital,*
*May* 8, 1845.

# X. *On the Elliptic Polarization of Light by Reflexion from Metallic Surfaces.*

*By the Rev.* BADEN POWELL, *M.A., F.R.S., F.G.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford.*

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IN a former paper, inserted in the Philosophical Transactions, 1843, Part I., I detailed observations on some phenomena of elliptic polarization by reflexion from certain metallic surfaces; but with reference only to one class of comparative results. From these I have been led to pursue the subject into other relations besides those at first contemplated; but, from various causes, have only been able at this interval to submit the results to the Royal Society as a sequel to my former observations.

The changes in the degree of ellipticity, investigated in my former paper, correspond to certain changes in the thickness of metallic *films*. If we now consider the case of reflexion from a *simple polished metallic surface*, and admit that in this case it may be supposed to take place by the penetration of the ray to a certain minute depth, or to some action of a thin transparent lamina of the metal, then, in like manner,—dependent on the law of metallic retardation,—the effect would vary with a difference in the *effective* thickness of the lamina, produced by changing the inclination of the incident ray; and that this is the case in general is well known, viz. that as the incidence is increased, the ellipticity increases up to a maximum, which occurs for most metals at an incidence between 70° and 80°, beyond which it decreases up to 90°.

The original researches of Sir D. BREWSTER*, to which we are indebted for the first investigation of these phenomena, afford a striking instance of the legitimate process of inductive inquiry in its first stage, in their total exemption from all reference to any physical theory. In these researches, besides the change in ellipticity with the incidence, there is also included the change in the virtual plane of polarization by metallic reflexion, which, though conjectured to be the same as that investigated by FRESNEL for transparent substances†, was only examined in detail at incidences at or near that for the maximum ellipticity, to which the author's object immediately restricted him. But for a series of metals *constant arcs* were accurately determined‡, which are the azimuths of polarization of the ray, restored to plane polarization after *two* reflexions from metal plates at the incidence for the maximum; while the ellipse, from which the appellation of "elliptic polarization" was derived, is a purely empirical representation of the varying arcs of incidence, considered as

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[*] Philosophical Transactions, 1830, Part II. [†] Ibid. p. 292. [‡] Ibid. p. 294.

radii, for the second reflexion to restore plane polarization, at all azimuths of the plane of second reflexion to the first.

Though the subject of metallic reflexion is still in a condition of great obscurity, as to the mechanical causes to which its peculiar character is referrible, yet the application of the undulatory theory at least enables us to trace and connect some of its laws, and in the attempt to pursue such an application to some further relations, the nature of my researches may be briefly explained as follows :—

1. So far as the objects of my former inquiry were concerned, it sufficed to take the formula there employed for the polarized rings in the simplified form resulting from supposing a common coefficient to the two component vibrations; the plane of original polarization inclined 45° to that of reflexion, and 90° to that of analyzation. With reference however to some of the facts connected with observations at different incidences and azimuths of the polarizer, as well as on other grounds, it seemed desirable to generalize that formula by removing the above-mentioned restrictions; and I have accordingly here given an expression for the rings in elliptic light of all degrees with general coefficients, and for all positions of the polarizer and analyzer; which, though without difficulty deducible, has not, as far as I am aware, been stated by any writer.

2. With respect to the general character of *the rings*, the slightest observation shows that the distinction between the dark and bright centred systems in *plane* polarized light, though *modified*, is not *lost*, in the *lower* degrees of *ellipticity*; it disappears only when the light becomes perfectly circular; when the distinction is only seen in the changed direction of dislocation.

When the plane of analyzation is inclined 45° between the rectangular directions, and generally in intermediate positions, the whole appearance is, as it were, *distorted*; the dark arcs nearest the centre are situated towards *one end* of the quadrants, instead of being in the middle; and in the succeeding rings, though less strongly marked, there is an apparent increase of intensity towards the same *end* of the quadrant, owing to a general shade of darkness in the *ground* towards that side*. Of this appearance, though it must have been constantly seen, as far as I know, no explanation has been published. In *circular* polarization it does not occur. In plane polarized rings the analogous case is that of the well-known system of eight dislocated sectors; which in ellipticity of lower degrees is combined with, and passes into, that just described. All this is expressed by my formula.

3. The restoration of elliptic to plane polarized light by means of FRESNEL's rhomb, and the determination of the ellipticity by the azimuth of the rhomb, though an obvious process, yet has not, as far as I know, been pursued for any series of metals. Such a set of observations I have accordingly made at the incidence for the maximum ellipticity, for a considerable range of metals, some metallic ores, and other reflecting substances. Also in a few principal cases I have made similar observations at other incidences from 80° up to 30°, at which the ellipticity disappears.

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* See Plate II. fig. 3.

4. In these cases the metallic reflexion performs the part of the first rhomb in **Fresnel's** experiment with two. If I rightly interpret Sir D. **Brewster's** process for a similar restoration, before referred to, and if the two metal plates are analogous to the two rhombs, in the *change of plane*, which he so accurately determined, after the second reflexion, at the maximum incidence, we may infer a correspondence with that produced in the rhomb; and that it is *equal to twice the azimuth of the rhomb.* And in fact I find the results from two such different methods agree very closely for all the pure metals; though for certain ores, very low in the scale, there are some discrepancies.

There is also a close agreement between these results and the azimuths of the plane of the ray restored to plane polarization by the action of a crystallized plate, as given by the same author for some of the principal metals*, which confirms the same inference.

5. The *changes of plane* for successive incidences are in general of a nature *analogous* to those in the reflexion from transparent bodies, but not the *same.*

At the incidence for the maximum, if the plane of the polarizer be first adjusted to give, *e. g.* the dark system, then on changing its plane to 45°, the analyzer, in order to restore what is analogous to the same, that is, the *darkest* system, must coincide with the plane of incidence, or its azimuth is 0°, in exact agreement with what obtains both by theory and observation in the reflexion from transparent bodies.

At *greater* incidences, to restore the same system, the analyzer must be moved through increasing arcs on *one* side of the plane of incidence, and at *lesser* incidences on the *other,* as for transparent bodies.

Following up these latter, as the incidence is successively diminished, the azimuth of the analyzer changes in a manner obviously *different* from that which obtains for transparent bodies, though of the same *general* character: and the increase is slightly different for different metals; but in all cases it approaches 45° as the incidence approaches the perpendicular.

In these cases the azimuth of the polarizer remains at 45°. If it be changed, that of the analyzer preserves a constant relation.

Though these observations are of an obvious nature, yet, as far as I know, none of the kind have been published for any series of metals. I have accordingly given such a set for various reflecting substances.

But though apparently simple in principle, the process is troublesome in practice, and affected by various causes of uncertainty and difficulty. Some apparent anomalies, especially, which caused the arcs at small incidences to appear to increase beyond 45°, for a long time caused me much perplexity.

The results however here offered, having been obtained with the use of every precaution, and being the means of a great number of repetitions, I trust, on the whole, may not be useless as a first attempt to determine these changes by direct observation.

6. The ellipticity at different incidences cannot be deduced (except at the max-

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* Philosophical Transactions, 1830, Part II. p. 311.

imum) from the rhomb observations without a knowledge of the change of plane: employing these latter data in combination with the former (3.), I have further estimated the ellipticity at different incidences for four principal metals.

7. For the application of the *undulatory theory* to these phenomena, we ought to be able to assign the law of metallic retardation, but this has not yet been done. The theory as here given indicates *the conditions of the maximum*, and shows in general *a change*, but not its *amount*.

Professor MACCULLAGH has however proposed, in accordance with a remarkable mathematical analogy, certain modifications of FRESNEL's formula, which he has reduced to calculation in the case of *steel*.

My *theoretical* formula gives rise to an expression for the change of plane, but involving undetermined functions of the retardation. *On deducing the corresponding terms from Professor* MACCULLAGH's *data, and introducing them into my formula, I find it gives a very close representation of the observed results for steel.* Thus Professor MACCULLAGH's empirical expression receives an additional confirmation in accordance with a direct deduction from the undulatory theory.

The rest of this paper is devoted to the details of the observations, and of the analytical investigation.

## THEORETICAL INVESTIGATION.

(1.) The original vibration in a plane P being

$$a \sin \frac{2\pi}{\lambda}(vt-x),$$

in general on reflexion in a plane R inclined to P by an angle $\xi$ (R′ being the plane perpendicular to R) it is resolved into

$$a \cos \xi \sin \frac{2\pi}{\lambda}(vt-x) \ \ldots \text{ in R},$$

$$a \sin \xi \sin \frac{2\pi}{\lambda}(vt-x) \ \ldots \text{ in R}'.$$

(2.) But in the case of *metallic* reflexion, one of these components is accelerated in phase by a quantity $\varrho$, and at the same time for the greater generality, supposing the coefficients unequal, or changing $a$ in the 2nd formula to $b$, and writing for brevity

$$\alpha = a \cos \xi, \quad \beta = b \sin \xi;$$

after metallic reflexion the component vibrations will be

$$\alpha \sin\left(\frac{2\pi}{\lambda}(vt-x)\right) \quad = \text{R},$$

$$\beta \sin\left(\frac{2\pi}{\lambda}(vt-x)+\varrho\right) = \text{R}'.$$

(3.) Here we may remark that these formulas give directly the equation to the elliptic vibrations, the ratio of whose axes is that of $\alpha$ to $\beta$, which vary at different incidences as well as with changes given to $\xi$; or $a$ and $b$ are also functions of the incidence, or of $\varrho$. When $\varrho=\frac{\pi}{2}$ if $\alpha=\beta$ the light is circular; this is never the case in any metal at the maximum, though in some the ratio approaches it. For some other value of $\varrho$ we may have $\alpha=\beta$, but this does not give circular polarization. When $\varrho=0$ the same formulas give the inclination of the plane of the rectilinear vibrations*.

(4.) On interposing a plate of crystal cut perpendicular to its axis, for any plane Q in the crystal passing through the axis, inclined to R by an angle $\varphi$, and to which Q′ is perpendicular, we have the vibrations

$$\text{R resolved into}\left\{\begin{array}{l}\text{R}\sin\varphi \text{ in Q}' \\ \text{R}\cos\varphi \text{ in Q.}\end{array}\right.$$

$$\text{R}' \text{ resolved into}\left\{\begin{array}{l}\text{R}'\cos\varphi \text{ in Q}' \\ \text{R}'\sin\varphi \text{ in Q.}\end{array}\right.$$

(5.) And on the general principle of resolution (observing that the resolved parts in one of the planes will be opposed), we have

$$\text{R}'\sin\varphi+\text{R}\cos\varphi=\text{Q}$$
$$\text{R}'\cos\varphi-\text{R}\sin\varphi=\text{Q}'.$$

The vibrations in Q′ form the ordinary ray O, and those in Q the extraordinary E. But after emergence the vibrations in Q are all further accelerated by $\theta$, or become

$$\alpha\sin\left(\frac{2\pi}{\lambda}(vt-x)+\theta\right),$$

$$\beta\sin\left(\frac{2\pi}{\lambda}(vt-x)+\varrho+\theta\right).$$

(6.) Thus we have

$$\left.\begin{array}{r}\beta\sin\left(\frac{2\pi}{\lambda}(vt-x)+\varrho\right)\cos\varphi \\ -\alpha\sin\left(\frac{2\pi}{\lambda}(vt-x)\qquad\right)\sin\varphi\end{array}\right\}=\text{O}\ldots\text{ in Q}'.$$

$$\left.\begin{array}{r}\beta\sin\left(\frac{2\pi}{\lambda}(vt-x)+\varrho+\theta\right)\sin\varphi \\ +\alpha\sin\left(\frac{2\pi}{\lambda}(vt-x)+\theta\qquad\right)\cos\varphi\end{array}\right\}=\text{E}\ldots\text{ in Q.}$$

(7.) Now if the analyzer be applied with the plane of analyzation A, inclined to R by an angle $\chi$, we shall have the angle $\text{AQ}=\psi=\chi-\varphi$, and $\text{AP}=\chi+\xi$.

The vibrations being again resolved in A and A′ perpendicular to it, we find

$$\text{O resolved into}\left\{\begin{array}{l}\text{O}\sin\psi \text{ in A}' \\ \text{O}\cos\psi \text{ in A.}\end{array}\right.$$

$$\text{E resolved into}\left\{\begin{array}{l}\text{E}\cos\psi \text{ in A}' \\ \text{E}\sin\psi \text{ in A.}\end{array}\right.$$

After analyzation the parts transmitted are those only in A, or

$$\text{O}\cos\psi-\text{E}\sin\psi.$$

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* See my Treatise on the Undulatory Theory, &c., p. 12.

(8.) On substituting the values of O and E, and arranging the terms, this is reducible to the form

$$H \sin\left(\frac{2\pi}{\lambda}(vt-x)\right)+K \cos\left(\frac{2\pi}{\lambda}(vt-x)\right),$$

where

$$\left.\begin{array}{l} \beta \cos\varphi \cos\psi \cos\varrho - \alpha \sin\varphi \cos\psi \\ -\beta \sin\varphi \sin\psi \cos\varrho \cos\theta \\ +\beta \sin\varphi \sin\psi \sin\varrho \sin\theta \\ -\alpha \cos\varphi \sin\psi \cos\theta \end{array}\right\} = H,$$

and

$$\left.\begin{array}{l} \beta \cos\varphi \cos\psi \sin\varrho \\ -\beta \sin\varphi \sin\psi \sin\varrho \cos\theta \\ -\beta \sin\varphi \sin\psi \cos\varrho \sin\theta \\ -\alpha \cos\varphi \sin\psi \sin\theta \end{array}\right\} = K.$$

Then, since the intensity I at any part of the image is expressed by

$$I = H^2 + K^2,$$

(9.) Squaring these quantities H and K, and taking the sum, after reduction, we ultimately find for any value of $\chi$, or position of the analyzer,

$$I = \left\{\begin{array}{l} (\beta^2 \cos^2\varphi + \alpha^2 \sin^2\varphi) \cos^2\psi \\ +(\beta^2 \sin^2\varphi + \alpha^2 \cos^2\varphi) \sin^2\psi \\ -\alpha\beta \sin 2\varphi \cos 2\psi \cos\varrho \\ -\alpha\beta \cos 2\varphi \sin 2\psi \cos\varrho \cos\theta \\ -\alpha\beta \sin 2\psi \sin\varrho \sin\theta. \end{array}\right.$$

(10.) Or, in order to see the consequences of changing the position of the analyzer, or the arc $\chi$, we must introduce it by substituting for $\varphi$ its value $\varphi = \chi - \psi$,

$$I = \left\{\begin{array}{l} (\alpha^2 \sin^2(\chi-\psi) + \beta^2 \cos^2(\chi-\psi)) \cos^2\psi \\ +(\alpha^2 \cos^2(\chi-\psi) + \beta^2 \sin^2(\chi-\psi)) \sin^2\psi \\ -\alpha\beta \cos 2\psi \sin 2(\chi-\psi) \cos\varrho \\ -\alpha\beta \sin 2\psi \cos 2(\chi-\psi) \cos\varrho \cos\theta \\ -\alpha\beta \sin 2\psi \sin\varrho \sin\theta. \end{array}\right.$$

(11.) On expanding and reducing this becomes—

$$I = \left\{\begin{array}{ll} (\alpha^2 \sin^2\chi + \beta^2 \cos^2\chi) \cos^4\psi \quad . \quad . \quad . \quad . \quad . & 1. \\ +(\alpha^2 \sin^2\chi + \beta^2 \cos^2\chi) \sin^4\psi \quad . \quad . \quad . \quad . \quad . & 2. \\ +2(\alpha^2 \cos^2\chi + \beta^2 \sin^2\chi) \sin^2 2\psi \quad . \quad . \quad . \quad . \quad . & 3. \\ -\frac{1}{2}(\alpha^2 - \beta^2) \sin 2\chi \sin 2\psi \cos 2\psi \quad . \quad . \quad . & 4. \\ -\alpha\beta \sin 2\chi \cos^2 2\psi \cos\varrho \quad . \quad . \quad . \quad . \quad . \quad . \quad . & 5. \\ +\alpha\beta \cos 2\chi \sin 2\psi \cos 2\psi \cos\varrho \quad . \quad . \quad . \quad . & 6. \\ -\alpha\beta \cos 2\chi \sin 2\psi \cos 2\psi \cos\varrho \cos\theta \quad . \quad . & 7. \\ -\alpha\beta \sin 2\chi \sin^2 2\psi \cos\varrho \cos\theta \quad . \quad . \quad . \quad . \quad . & 8. \\ -\alpha\beta \sin 2\psi \sin\varrho \sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . & 9. \end{array}\right.$$

(12.) This formula is general for all positions of the polarizer and analyzer, and for light of all degrees of ellipticity. If we had taken (as in my former paper) $\psi=(45-\varphi)$, and at the same time supposed $\alpha=\beta=1$ (which is equivalent to the assumption then made for simplification), the formula (9.) would become at once the same as in that paper.

The first terms independent of $\theta$ express the intensity of the *ground* on which, as it were, the rings are formed: those involving $\varrho$ vary with the incidence or degree of ellipticity: those involving $\theta$ give the rings; the last only being retained when the ellipticity is a maximum, and disappearing for plane polarization at the incidence 0.

From these formulas we at once trace all the well-known phenomena of the rings in plane and elliptic light, by following the changes in formula (9.) on advancing into the adjacent quadrants, or supposing $\psi$ to become $\psi+90$, and by consequence changing also $\varphi$ into $\varphi+90$; which gives a change of sign in the terms involving $\sin 2\psi$, $\cos 2\psi$, $\sin 2\varphi$, $\cos 2\varphi$.

Again, with regard to changes in the analyzer, it is evident that whatever be the value of $\chi$ if we increase it by 90°, we shall have to substitute in (10.) $\cos(\chi-\psi)$ for $\sin(\chi-\psi)$ and *vice versâ*; as well as $-\sin 2(\chi-\psi)$ for $\sin 2(\chi-\psi)$, and $-\cos 2(\chi-\psi)$ for $\cos 2(\chi-\psi)$, or, on the whole, the expression is obviously complementary, except the last term.

(13.) In any case on giving successive values to $\psi$ round the rings, at those points where the sines or cosines vanish, the disappearance of any term when accompanied by a change of sign indicates (so far as that term affects the total intensity) a change from dark to bright at that point, or a complementary character in the adjacent portions of the image; when without a change of sign it indicates a simple maximum or minimum of light, in the rings or in the ground, according as the terms affected involve $\theta$ or not; and for light of different ellipticities according to the value of $\varrho$.

Thus for the values of $\chi$ in general, in (11.)—

At $\psi=0$, or 90°,

$$\left.\begin{array}{r}\text{terms 1, 2, 3, for the ground}\\ \text{8, for the rings}\end{array}\right\}\text{ disappear without change of sign.}$$

$$\left.\begin{array}{r}\text{4, 6, for the ground}\\ \text{7, 9, for the rings}\end{array}\right\}\text{ disappear with change of sign.}$$

At $\psi=45$,

5, for the ground, disappears without change of sign.

$$\left.\begin{array}{r}\text{4, 6, for the ground}\\ \text{7, for the rings}\end{array}\right\}\text{ disappear with change of sign.}$$

In *general* then there are dislocations of the *rings*, with more or less complete complementary changes in the *ground* both at the quadrants and half-quadrants.

At the maximum ellipticity, since terms 5, 6, 7, 8 disappear, there are dislocations only at $\psi=0$, with a change in the *ground* at $\psi=45$, or a gradual decrease of brightness from one *end* of the quadrant to the other, which is exactly the appearance observed. In plane polarized light we have the system of eight dislocated sectors, intermediate between the dark and bright systems. In the lower degrees of ellipticity this is modified by, and passes into, that just described.

(14.) We may illustrate the application of the formula by one or two particular cases:—

1st. If we suppose at some incidence $\alpha=\beta$ while $\rho<\frac{\pi}{2}$, then $\chi=45°$ will give branches with dislocation at $\psi=0°$, but none at $\psi=45°$; that is the nearest approach to the dark system. This agrees with formula (15.), where in this case I is a minimum when $\chi=45°$, also with (18.).

2ndly. On the same supposition $\chi=0$ will give complementary changes both in the ground and in the rings at $\psi=0$, and similar changes, though less conspicuous, at $\psi=45$; that is the intermediate system.

3rdly. For the general values of $\alpha$ and $\beta$ at the maximum $\cos\rho=0$; and $\chi=0$ gives branches with dislocation at $\psi=0$, but no change at $\psi=45°$; or the darkest system. But $\chi=45°$ will give (since $\alpha>\beta$) a complementary change in the ground at $\psi=45°$, and branches with dislocation at $\psi=0$; or the distorted system.

But if in this case $\alpha=\beta$, or the polarization be *circular*, the term (4.) disappears, and there is no distorted system in any position of $\chi$.

Observation shows this to be the case in perfectly circular light, and very nearly so in the higher degrees of ellipticity.

(15.) For the branches, when $\psi=0$, for $\chi$ in general we have

$$I=\alpha^2\sin^2\chi+\beta^2\cos^2\chi-\alpha\beta\sin 2\chi\cos\rho.$$

Hence, on making successively $\cos\rho=1$, $\cos\rho=0$, $\cos\rho=-1$, &c., it is obvious that the intensity of the branches for the maximum ellipticity would be a mean between that in the dark and bright systems of plane polarized light if $\alpha$ and $\beta$ were the same in the respective cases, which we shall see is the case; at all events, this relation of the intensities agrees with observation as far as the eye can judge.

(16.) Again, for the maximum ellipticity,

$$I=\beta^2+(\alpha^2-\beta^2)\sin 2\chi,$$

which can never be $=0$; or the branches are never absolutely dark; but it is evidently a minimum when $\chi=0$, and a maximum when $\chi=90°$, in which cases respectively $I=\beta^2$, or $I=\alpha^2$. If the polarization were circular these values would be equal, or the brightness the same in all positions of the analyzer.

(17.) For incidence 0°, the expression (15.) being made $=0$, or,

$$I=\alpha^2\sin^2\chi+\beta^2\cos^2\chi-2\alpha\beta\sin\chi\cos\chi=0,$$

we have for the position of the analyzer for absolutely dark branches, as in (3.),

$$\alpha\sin\chi-\beta\cos\chi=0,$$

or

$$\tan\chi=\frac{b}{a}\tan\xi.$$

But observation shows in this case that tan $\chi=45^\circ$ when $\xi=45^\circ$ in all instances, hence for incidence 0° $a=b$.

(18.) More generally, differentiating (15.) in respect of $\chi$, we find for any given value of $\varrho$, that is of $\alpha$ and $\beta$, the value of $\chi$ for the minimum, or darkest branches,

$$\tan 2\chi=-\frac{2\alpha\beta\cos\varrho}{\alpha^2-\beta^2},$$

or we might deduce directly

$$\tan\chi=-\frac{\alpha^2-\beta^2}{2\alpha\beta\cos\varrho}\pm\sqrt{\left(1+\frac{(\alpha^2-\beta^2)^2}{4\alpha^2\beta^2\cos^2\varrho}\right)}.$$

Hence we may make the same inferences as before.

And if when $\cos\varrho=0$ we have also $\alpha=\beta$, or *circular* vibrations, it is worth while to observe that there results

$$\tan 2\chi=\frac{0}{0}.$$

But in general for the change of plane, or of $\chi$, this formula does not assign any precise values, since the form of the function of $\varrho$ involved in $\alpha$ and $\beta$ is unknown.

(19.) In the absence of any *theoretical* law I have had recourse to the *empirical* modification of FRESNEL's formula proposed by Professor MACCULLAGH*. And availing myself of the computed values which he has given, in the case of steel, for the coefficients of the component vibrations $\alpha\,\alpha'$ (assuming $\alpha'=\beta$ in my notation) and the retardations $\delta\,\delta'$ (where $\delta-\delta'=\varrho$ in my notation), I have deduced the values of the product $\alpha\,\alpha'$, of $\alpha^2-\alpha'^2$, and of $\cos\varrho$, and introducing these in formula (18.), I find the resulting values of $\chi$ in close agreement with those given by observation. The elements of this computation and its results are exhibited in Table IV.

## APPARATUS.

The general principle of my apparatus will be apparent from the nature of the experiments, but it may not be superfluous (especially for those who may wish to pursue similar observations) to annex an outline of the construction, which, after trial of various forms, I have found best to unite the requisite conditions for the purpose in view; while it is readily convertible into an ordinary polariscope; besides admitting of the addition or substitution of other parts, when required, for different objects.

The accompanying Plate II. fig. 1 gives a general view of the arrangement and will sufficiently explain itself: the polarizing part (P) contains a NICOL prism which can be turned in azimuth, measured by a graduated circle; a condensing lens (L) is also attached to it.

The analyzing part (A) contains in the eye-piece (E) a lens, a calc-spar, and a tourmaline; and bears a graduated circle, on which the azimuth of analyzation is read off.

The metal under examination is placed on the support (R), which can be raised or lowered as required; and should be capable of a slight inclination for better adjustment.

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* Reports, Royal Irish Academy, October 1836.

The middle part or hinge (M) is surrounded by a graduated vertical circle, by which the parts (P) and (A) can be set at any angle to each other: they are attached to it by projecting arms: the whole is moved by the joint (K) till the reflected light from (R) comes distinctly to the eye through (E), when (it is easily seen) the angle of incidence will be *half* that measured on (M).

The zero of (M) is found by adjusting (P) and (A) with their axes in one line (or reducing the instrument to an ordinary polariscope). The hinge should be capable of being firmly clamped.

In observations at very great incidences it will be easily seen to be necessary to have the arms carrying (P) and (A) so fixed, that when the axes of the tubes are brought into one line there shall be a considerable space between their inner ends: there should be also a slight motion about the axis of the arm for adjustment in (P).

In observations at very small incidences, it is most convenient to throw the light on to (P) by means of a small mirror placed in a proper position.

Fig. 2 represents the mode of applying the **Fresnel** rhomb (F) to the analyzing part, the rest of the arrangement remaining the same. The eye-piece (E) is removed to a cap on the top of the rhomb; while the bottom of the rhomb is attached to a short tube, which fits into the aperture before occupied by the eye-piece.

Fig. 3 represents the appearance of the rings in elliptic light when the analyzer is at 45° between the dark and light systems.

## OBSERVATIONS.

The determination of the precise position of the analyzer at which the maximum or minimum brightness is attained, is from the nature of the case open to considerable uncertainty. But the intervention of the *rings*, instead of using the simple analyzer, affords some aid in this respect, since the change in the nature and form of the rings offers a more ready guide to the eye; especially in elliptic light, where there is never a total evanescence. Still the undefined nature of the object observed precludes minute numerical accuracy, and the results in the following tables must be regarded as no more than approximations, though derived from the means of a great number of repetitions. In taking these means, I have omitted fractions of a degree as bearing an appearance of accuracy quite illusory.

The greatest care is necessary in the adjustments, especially of the polarizer. They were remade for each set of observations. That for the polarizer to obtain the zero or coincidence with the plane of reflexion, was found by varying the azimuth till the light was perfectly restored to plane polarization; the analyzer being in the position for dark branches, the zero of its circle was determined at the same time.

In the observations at different incidences, in order to secure the constancy of its inclination to the plane of incidence, the polarizer was adjusted to zero before observation at each incidence. For some of the ores, &c. which reflect but little light, the arcs must be taken as mere estimations. I have found some peculiar discordances between different sets of observations, especially in silver and copper: those given are the means.

The observations here annexed in a tabular form consist of,—

1. Those with **Fresnel**'s rhomb for ascertaining from the azimuth ($\gamma$) for the restoration of plane polarization, the ellipticity at the incidence for the maximum; or giving

$$\epsilon=\left(\frac{\beta}{\alpha}\right)_m=\tan\gamma_m.$$

These results for the principal metals and other substances are seen in Table I., columns 3 and 4.

Again, in the observations with the rhomb at azimuth $\gamma$, the plane of the emergent ray is inclined by $2\gamma$ to the original plane. In Sir D. **Brewster**'s experiments with two metal plates it is inclined $45+\varphi$. The results are here compared in columns 1 and 2, and sufficiently show that we have

$$\gamma=\frac{45+\varphi}{2}$$

for all the pure metals.

Also we may remark, that Sir D. **Brewster**'s empirical ellipse has the ratio of its axes determined by $\sin 2\varphi$, and is therefore different from the undulatory.

The same author also gives* the azimuths of the plane of the ray restored to plane polarization by a crystallized plate for several metals, as follows:—

| | | | |
|---|---|---|---|
| Pure silver . . . | 42° | Speculum . . . | 32° |
| Copper . . . . | 36° 30′ | Steel . . . . . | 30° 30′ |
| Mercury . . . . | 35° | Lead . . . . . | 26° |
| Platinum . . . . | 34° | Galena . . . . | 17° 30′ |

In each instance it will be seen (on comparison with Table I.), that as nearly as possible the arc $=\frac{45+\varphi}{2}$; with the exception of galena.

2. Observations for the values of $\chi$ at successive incidences, while $\xi$ remains at 45°.

These series of arcs are given in Table II., column 1, for the two metals of greatest and least maximum ellipticity and two intermediate; and in Table III. for a number of others.

3. Observations for the ellipticity at different incidences.

In general the ellipticity is measured by the inclination of the rhomb ($\gamma$) to the plane of previous polarization.

For the maximum ellipticity, since $\chi=0$, it follows that $\gamma$ is correctly measured from the plane of reflexion. But at *other* incidences $\gamma$ must be corrected by the change of plane of polarization due to that incidence, or we must take $(\gamma-\chi)$.

In Table II. (columns 2 and 3) are given the observed values of $\gamma$ for four principal metals at different incidences, and the corresponding ellipticities ($\iota$) or tan $(\gamma-\chi)$. These results give on the whole a view of the changes of ellipticity agreeing with the general appearance of the rings; though in copper the diminution appears too rapid.

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* Philosophical Transactions, 1830, Part II. p. 311.

TABLE I.

| Metal. | Values of $\phi$ (BREWSTER). | $\frac{45+\phi}{2}$. | Azimuth of rhomb $=\gamma$. | Ellipticity $\iota=\tan\gamma$. |
|---|---|---|---|---|
| Silver, pure ........ | 39° 48′ | 42° 24′ | 42° | ·932 |
| Silver, common .... | 36 | 40 30 | 40 | ·839 |
| Gold, pure ........ | 35 | 40 | | |
| Gold, common...... | 33 | 39 | 40 | ·839 |
| Brass.............. | 32 | 38 30 | 38 | ·781 |
| Copper ............ | 29 | 37 | 38 | ·781 |
| Mercury .......... | 26 | 35 30 | 35 | ·700 |
| Platinum .......... | 22 | 33 30 | 34 | ·674 |
| Palladium.......... | .... | .... | 34 | ·674 |
| Speculum .......... | 21 | 33 | 31 | ·600 |
| Bismuth .......... | 21 | 33 | 34 | ·674 |
| Zinc .............. | 19 10 | 32 5 | 32 | ·624 |
| Steel.............. | 17 | 31 | 30 | ·577 |
| Iron .............. | .... | .... | 29 | ·554 |
| Antimony.......... | 16 15 | 30 37 | 31 | ·600 |
| Lead.............. | 11 | 28 | 28 | ·531 |
| Tinned plate........ | .... | .... | 32 | ·624 |
| Plated copper ...... | .... | .... | 32 | ·624 |
| Iron pyrites ........ | 14 | 29 30 | 29 | ·554 |
| Galena ............ | 2 | 23 30 | 24 | ·466 |
| Specular iron ore.... | 0 | 22 30 | 24 | ·466 |
| Tempered steel, yellow | .... | .... | 20 | ·363 |
| Tempered steel, blue . | .... | .... | 15 | ·267 |
| Plumbago.......... | .... | .... | 15 | ·267 |
| Decomposed glass .. | .... | .... | 7 | ·122 |

TABLE II.

| Pure silver ($\xi=45°$). | | | | | Copper ($\xi=45°$). | | | |
|---|---|---|---|---|---|---|---|---|
| | Observed values of | | | | Observed values of | | | |
| $\iota$. | $\chi$. | $\gamma$. | $\gamma-\chi$. | $\iota$. | $\chi$. | $\gamma$. | $\gamma-\chi$. | $\iota$. |
| 30 | 42 | 45 | 3 | ·052 | 44 | 45 | 1 | ·017 |
| 40 | 36 | 45 | 9 | ·158 | 40 | 45 | 2 | ·034 |
| 50 | 31 | 45 | 14 | ·249 | 23 | 44 | 11 | ·194 |
| 60 | 25 | 44 | 19 | ·344 | 24 | 43 | 19 | ·344 |
| 70 | 10 | 43 | 34 | ·674 | 10 | 39 | 29 | ·554 |
| | 73) 0 | 42 | 42 | ·932 | 73) 0 | 38 | 38 | ·781 |
| 80 | −25 | 45 | 20 | ·363 | −21 | 40 | 19 | ·344 |

| Steel ($\xi=45°$). | | | | | Lead ($\xi=45°$). | | | |
|---|---|---|---|---|---|---|---|---|
| | Observed values of | | | | Observed values of | | | |
| $\iota$. | $\chi$. | $\gamma$. | $\gamma-\chi$. | $\iota$. | $\chi$. | $\gamma$. | $\gamma-\chi$. | $\iota$. |
| 30 | 43 | 45 | 2 | ·034 | 45 | 45 | 0 | ·0 |
| 40 | 41 | 45 | 4 | ·069 | 42 | 45 | 3 | ·052 |
| 50 | 34 | 43 | 9 | ·158 | 30 | 43 | 13 | ·230 |
| 60 | 29 | 41 | 13 | ·230 | 24 | 42 | 18 | ·324 |
| 70 | 15 | 35 | 20 | 363 | 8 | 33 | 25 | ·466 |
| | 75) 0 | 30 | 30 | 577 | 72) 0 | 28 | 28 | ·531 |
| 80 | −19 | 34 | 15 | ·267 | −14 | 35 | 21 | ·383 |

## Table III.

| $i$. | Observed values of $\chi$. $\xi=45°$. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Gold. | Brass. | Mercury. | Platinum. Palladium. | Bismuth. | Zinc. | Antimony. | Speculum. |
| 30 | 44 | 43 | 45 | 44 | 43 | 44 | 44 | 44 |
| 40 | 40 | 42 | 44 | 43 | 42 | 43 | 43 | 42 |
| 50 | 36 | 39 | 42 | 40 | 41 | 41 | 42 | 40 |
| 60 | 17 | 35 | 39 | 38 | 36 | 39 | 38 | 32 |
| 70 | 0 | 15 | 29 | 32 | 23 | 25 | 25 | 17 |
| | | 72) 0 | 78) 0 | 78) 0 | 74) 0 | 77) 0 | 75) 0 | 76) 0 |
| 80 | −30 | −19 | − 7 | −10 | −25 | −10 | −20 | −20 |

| $i$. | Observed values of $\chi$. $\xi=45°$. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Plated copper. | Tinned plate. | Tempered steel, yellow. | Tempered steel, blue. | Decomposed glass. | Specular iron ore. | Galena. | Plumbago. |
| 30 | 43 | 44 | 43 | 43 | 43 | 43 | 44 | 45 |
| 40 | 41 | 43 | 40 | 41 | 42 | 42 | 43 | 44 |
| 50 | 40 | 41 | 26 | 35 | 38 | 35 | 40 | 35 |
| 60 | 37 | 40 | 0 | 10 | 9 | 27 | 30 | 24 |
| | | | | 62) 0 | 62) 0 | | | |
| 70 | 20 | 22 | −25 | −21 | −35 | 17 | 15 | 10 |
| | 72) 0 | 77) 0 | .... | .... | .... | 77) 0 | 72) 0 | 75) 0 |
| 80 | −30 | −15 | −45 | −44 | −44 | −10 | −20 | −15 |

## Table IV.

| Steel. | | | | | |
|---|---|---|---|---|---|
| $i$. | From MacCullagh's data. | | | Values of $\chi$. | |
| | $\alpha\alpha'$. | $\alpha^2-\alpha'^2$. | $\epsilon=\delta-\delta'$. | Calculated by (18). | Observed. |
| ° | | | ° | ° ′ | ° |
| 0 | ·526 | 0·0 | 0 | 45 | nearest 0° } 45 |
| 30 | ·522 | ·100 | 8 | 42 14 | 43 |
| 45 | ·408 | ·231 | 19 | 36 40 | 36 |
| 60 | ·474 | ·421 | 41 | 29 45 | 29 |
| 75 | ·451 | ·610 | 90 | 0 | 0 |
| 85 | ·682 | ·456 | 150 | −28 5 | −27 |
| 90 | 1·0 | 0·0 | 180 | −45 | nearest 90° } −43 |

## POSTSCRIPT.

Received May 8, 1845.

Since the foregoing paper was communicated I have obtained some additional instances of elliptic polarization, which may be not uninteresting in connexion with those therein mentioned.

Besides plumbago (in which the proportion of metal present is at least very variable and small) I have now observed a slight, but quite unequivocal ellipticity in the reflexion from *China ink*, which is wholly non-metallic. It is at its maximum at an incidence of 62°, and its azimuth of restoration by the rhomb is about 5°.

I have examined also *chromate of lead*, which gives very small ellipticity, which is at a maximum at an incidence of 70° (agreeing well with the mean refractive index), and the azimuth of the rhomb is about 6°.

## XI. *Electro-Physiological Researches.—First Memoir. The Muscular Current.*

*By Signor* Carlo Matteucci, *Professor in the University of Pisa, &c. &c.*
*Communicated by* Michael Faraday, *Esq., F.R.S., &c. &c.*

Received May 7,—Read June 5, 1845.

My only resource for showing the Royal Society how grateful I feel for the distinction lately accorded to me, is the communication of some fresh researches on electro-physiological phenomena.

The exposition of these researches will form the subject of the present and subsequent memoirs.

From the commencement of my studies on this subject, my principal aim has always been to reduce the experiments of electro-physiology to the simplest possible form, so that they may be repeated without the aid of very expensive instruments, or such as require great skill and practice in the management.

It is for this reason that I have dwelt long upon the phenomena which the electric current occasions in its passage along the nerves of an animal recently killed. The galvanoscopic frog, the mode of preparing which, together with its use and all its details, I have described in my Traité des Phénomènes Electro-Physiologiques des Animaux, page 51, is indubitably a very delicate galvanoscope, and free from all error. By means of the galvanoscopic frog properly applied, it is easy to ascertain the direction of the current which traverses the nervous filament of the frog itself. There is only this to be observed, that it is essential to the occurrence of this indication to wait until the frog be sufficiently weakened; and that in spite of this precaution, in every series of experiments we find some one frog in which, although we always have the signs of the electric current, yet contraction fails to take place when the circuit is closed with the direct current, and when it is broken with the inverse.

A new method of employing the frog, which I shall presently describe, adapts itself better than the galvanoscopic frog to the demonstration of the existence and direction of the muscular current, and of the proper current of the frog, and therefore supersedes the necessity of a galvanometer. For this purpose the frog is prepared in the ordinary manner of Galvani, that is to say, it is cut in half through the middle of the vertebral column, skinned, and the viscera removed. It is then easy, with the help of scissors (introducing them under the lumbar plexuses), to remove the greater part of the pelvis of the frog, leaving the above-mentioned plexuses intact;

finally, the frog is divided into two parts by cutting the juncture of the two thigh-bones. In this way there remain two halves of the frog united together organically by their spinal nerves. When this frog is required to be used for the purpose of discovering the presence and direction of the muscular current, it should be disposed upon an insulating plane in such a manner that its two extremities or claws dip into two separate recipients. Joining these two recipients with strings of cotton or thread, soaked with the same liquid as that contained in the recipients themselves, or with a strip of paper similarly wetted, no sign of contraction is ever produced, therefore no current is in circulation. This last fact may easily be proved by closing the circuit with the two ends of the platinum wire of a delicate galvanometer, provided we can be perfectly certain of the homogeneity of the substance of the extremities of the wires. And it will be seen that it cannot be otherwise, on reflecting that each half of the frog constitutes an electro-motor element of the proper current, so that, in the above-described manner of using the prepared frog, there are always two equal currents circulating in contrary directions, and which consequently neither excite contractions, nor deflect the needle of the galvanometer.

There is nothing easier, and at the same time more decisive, than the confirmation of the existence of the muscular current and of its direction.

A pile consisting of thighs of frogs, or of muscles of other animals, should be prepared in the manner I have described in my work that I have quoted above. The two extremities of this pile (the internal surface of the muscle on the one hand, and the external on the other) should dip in distilled or spring water. When the frog is prepared as already described, and stretched upon the insulating plane, the extreme cavities of the pile are made to communicate with the two recipients in which the claws of the frog are immersed, by means of strings of thread or cotton soaked with water (Plate III. fig. 1.). The frog is then distinctly seen to contract both on closing and on breaking the circuit; but both limbs do not contract equally, since that which is traversed by the current, and which consequently is near that extremity of the pile which is formed by the internal surface of the muscle, contracts on closing the circuit with the direct current, while, on the contrary, the other limb, which is near the extremity of the pile formed by the external surface of the muscle, contracts on breaking the circuit. Simply by the aid of the frog so prepared, it is possible to confirm the principal laws of the muscular current, which I have already discovered with the galvanometer. Thus it happens that the contractions of the galvanoscopic frog increase proportionally with the number of elements; and they are the same for a pile formed of muscular elements deprived of all visible nervous filaments, as for a pile the muscular elements of which are intact. The same takes place operating with a pile composed of muscular elements taken from frogs killed by the action of narcotic poisons, carbonic acid, prussic acid, &c. Finally, with the galvanoscopic frog it is easy to discover the immense difference which exists between the signs of the muscular current, occurring some time after death in piles composed of the same number of muscular elements, but taken from different animals, as frogs, eels, or pigeons. The signs of the current diminish in a rapid ratio as we ascend in the scale of animals upon which we operate.

Hitherto I have merely exhibited experiments which confirm my former conclusions. I have simply sought to show how that without a very delicate galvanoscope, and with the galvanoscopic frog alone, any person may be enabled to demonstrate the principal laws of the muscular current.

It has always been an object of peculiar interest to me, in the study of the muscular current, to establish fresh experimental proof, or to repeat and extend my former ones; all which have led me to conclude that the existence and intensity of the muscular current depend upon the existence and intensity of the changes of structure and composition, which constitute the nutrition of the muscle.

Nevertheless, before entering upon the exposition of my researches instituted in this view, I will describe some fresh facts, which, although they may be anticipated, notwithstanding, better serve to fix the origin of the muscular current.

With a pile of half thighs of frogs I have distinctly obtained the decomposition of iodide of potassium. To effect this, I soak a piece of paper in a solution of this substance, and upon it, about the distance of a line apart, I place the extremities of two platinum wires, the other ends of which dip in the fresh water which fills the extreme cavities of the pile. To facilitate and expedite the decomposition of the hydruret, I increase the extent of those portions of the platinum wires which are immersed in the cavities of the pile, by twisting the extremities into a coil; I am also in the habit of further wetting the paper soaked with the solution of hydruret of potassium, with a solution of starch paste, to which I add a few drops of chlorine. After the circuit has remained closed a few seconds, a blue or a yellow spot is formed around the wire which communicates with the cavity in which the external surface of the muscle is immersed.

With a pile of twenty elements of half thighs of frogs, I have likewise distinctly obtained signs of tension, by means of a tolerably delicate condenser. To this intent I put one extremity of the pile in communication with the ground, and the other with the plate of the condenser. I have frequently repeated the experiment, at one time establishing a communication between the internal surface of the muscle and the condenser, and the external surface with the ground; at another time I have reversed this order. I have likewise observed the phenomena which ensue on putting each of the extremities of the muscular pile in communication with one of the plates of the condenser. In every case the electroscope has constantly exhibited signs of a negative charge upon the internal surface of the muscle, and of a positive charge upon the external surface.

Again, I was desirous of ascertaining how the signs of the muscular current were affected on excluding the air from contact with the pile. For this purpose I employed the receiver commonly in use for the experiments of electricity *in vacuo*, or in other gases than air. The two platinum wires are fastened to the metallic rod which moves in the tube in the centre of the receiver; one of the wires, however, is insulated from the rod by a layer of gum-lac which intervenes where the wire encircles the rod. These two wires are twisted into the shape of a pitchfork, and so diverge from one another, that on pushing the rod down the two extremities enter the extreme cavities of the muscular pile (fig. 2.). I rapidly exhausted the air in the receiver, and then connected the platinum wires with the galvanometer. I have repeated the experiment while the air was exhausted, and immediately after admitting the air again into the receiver. The direction of the current has never varied, nor have I perceived any very great difference in the intensity and duration of the current in the different modes of conducting the experiment.

It will be readily understood from the description of the apparatus employed for operating in a vacuum, how easy it was to adapt it to experiments in other gases: I have used hydrogen and carbonic acid.

I think it important to describe minutely the results obtained in these different experiments. I began with a pile composed of twenty muscular elements, or half thighs of frogs, placing it under the receiver, and I filled the cavities of the pile with well-water, after ascertaining that there was no sign of a current on immersing the ends of the wire in the same liquid. In less than five minutes the frogs were killed and the pile prepared. In performing these comparative experiments, I have made use of frogs caught on the same day and in the same pool. In all these experiments the circuit was kept closed, and the duration of the current in the galvanometer observed for several hours successively. The following are the numbers obtained in the different experiments.

Operating in atmospheric air with a pile of twenty elements of frogs, the deflection in my galvanometer was so strong that the needle reached 90°, oscillated, then gradually returned towards 0°. At about 30° the needle begins to be stationary, or at least it retrogrades considerably more slowly than at first. Every ten minutes I noted down the deviations, which are the following: 15°, 9°, 5°, 4°, 3½°, 3½°, 3½°, 3½°. At the expiration of two hours the deflection was the same. The circuit was then broken, and the extremities of the wires immersed in pure water, the current produced was 70°, and its direction was contrary to the first when the circuit was closed with the muscular current. This was evidently the secondary current which at the commencement of my researches I showed to be the cause of the rapid decline of the muscular and proper current in those cases where the circuit is kept closed. I have twice repeated this same experiment with the same results.

I have constructed a third pile similar to the two already described, which I have put under the receiver mentioned above, and have exhausted the air to that degree of rarefaction that the mercurial column showed only one inch of pressure. I could not attain to a more complete degree of rarefaction on account of the aqueous vapour which was continuously formed. I then closed the circuit, and the deflection at first was 85°; as usual the needle oscillated, retrograded, and began to be stationary towards 30°. The following numbers show the degree of deflection at intervals of ten minutes, care having been taken to maintain constantly the degree of rarefaction unaltered. After the first ten minutes the deviation was 15°, 10°, 7°, 5°, 5°, 4°, after two hours the deflection was fully 3°. On admitting the air into the receiver the needle advanced two or three degrees, then again returned to its deflection of 3°. This slight increase in the strength of the current occurs, as we shall presently see, whatever be the gas introduced into the receiver; it is also caused by working the air-pump while the circuit is closed, and this is probably owing to the liquid contained in the cavities of the pile being put in motion, so that the wires are more or less immersed. The lesser deviation obtained in this third experiment on first closing the circuit was very probably owing to the frog having been killed rather longer than the others, to the muscular elements immediately beginning to dry in rarefied air, and to some bubbles of air which adhere to the platinum wires when the pump is worked.

I next killed forty other frogs, and with them I composed two piles consisting of twenty elements each pile. I tried the effect of each of these piles separately in contact with the air; in one of them the first deflection was 85°, in the other 88°. I then put one of these piles under the receiver and exhausted the air; I closed the circuit, and the deflection was 81°. The needle oscillated, retrograded as usual, and remained fixed at 15° at the expiration of ten minutes. I now introduced a sufficient quantity of oxygen gas to fill the receiver. The needle oscillated slightly on admitting the gas, then continued retrograding, and after a lapse of thirty minutes it marked 8°, and at the end of another half-hour it showed 4°.

After this I placed the other pile under the receiver, exhausted the air, and closed the circuit. The first deviation of the needle was 65°. This difference is naturally owing to the length of time the frogs had been killed, that is, all the time taken up by my first experiment. Leaving the circuit closed, the needle as usual continued to retrograde, becoming stationary at 4°, as did the other pile immersed in oxygen. Finally, I re-admitted the air, and the deflection was not increased.

These experiments are sufficient to show that the muscular current neither varies in intensity nor in duration, after the death of the animal, from keeping the muscles from which it is obtained either in oxygen or in air reduced to a pressure equivalent to one inch of mercury.

I will now describe the results obtained from operating in the manner above described, in hydrogen gas. The singularity which this gas offers could not certainly have been anticipated before the experiment.

As usual I prepared a pile of twenty elements, half thighs of frogs; I placed it under the receiver, and previous to exhausting the air I completed the circle, and the deflection was 85°: the circuit was left closed. I then rapidly exhausted the air and substituted hydrogen gas in its place. After the circuit had been closed ten minutes, the needle of the galvanometer remained stationary at 15°. But then instead of continuing to retrograde it began to advance, so that the deflection was 50° at the end of ten minutes. I broke the circle by drawing the rod up, and when the needle had returned to 0° I again completed the circuit; the needle now advanced to 90° in the usual direction of the muscular current, and remained fixed at 55°. From this point the needle of the galvanometer descended very slowly, being at 40° at the end of an hour. I then exhausted the hydrogen and re-admitted air, and the needle returned to 12°, continuing to recoil, but still more slowly than in the other experiments.

I repeated this same experiment with precisely the same results; that is to say, the needle descended as usual before the hydrogen was let into the receiver; after the introduction of the gas it advanced to 50°. I then produced a vacuum and again admitted the air, and the needle again descended, still however keeping up a greater deflection than there would have been if the hydrogen had never been used. I have been able, several times with the same pile, to observe the alternations of the effects produced by air and by hydrogen gas. Prolonging the contact of the hydrogen for some time, I have constantly observed that when that gas was exhausted and atmospheric air substituted for it, the final deflection of the needle, taking into account the time elapsed since the preparation of the pile, and *cæteris paribus*, was much greater than it would have been if no hydrogen had been introduced into the receiver. Finally, I will mention another experiment performed by closing the circuit with the usual muscular pile after having filled the recipient with hydrogen. The first deflection was the usual one, and then followed 47°, 41°, 40°, 38°, 37°, 35°, 34°, 32°, 31°, 30°. These signs of deflection were noted down at intervals of ten minutes. After six hours the needle was stationary at 25°. When hydrogen is not used, that is in atmospheric air, *in vacuo*, or in oxygen, the deflection does not exceed 5° with the usual pile of twenty elements, after the circuit has remained closed an hour.

Although I could not attribute this singular difference produced by the presence of hydrogen upon the muscular pile to the action of this gas upon the source of electricity in the muscles, nevertheless it appeared to me important to discover the cause of this difference. I very quickly prepared forty elements (half thighs of frogs), using every possible precaution to have all those circumstances equal in all the conditions which are known to influence the muscular current. Thus, two individuals prepare the frogs at the same time, each frog is divided into halves, and two separate heaps are made, from each of which twenty elements, or half thighs, are selected. I leave twenty of these elements exposed to the air, and the others in an atmosphere of hydrogen by means of the receiver.

At the expiration of forty minutes I take these twenty elements out of the hydrogen, and compose the pile, and I do the same with the other elements left in contact with the atmosphere. I oppose the two piles to one another in the manner I have described in my work quoted above, for the purpose of discovering the differential current. This done, I determine the intensity of the muscular current in each of the piles, taking note of the first deflection, and of that which the needle indicates after the circuit has been closed ten minutes. In another experiment performed in exactly the same manner, I confronted the current of one muscular pile, the elements of which had been in hydrogen, with another, the elements of which had been in air highly rarefied. Finally, before putting the muscular elements in hydrogen gas and in rarefied air, I measured the muscular currents of each of these piles, in order to compare them with those which were to follow. I should be too long if I were to report all the numbers of the different experiments which I performed. The conclusion to be drawn from them all is extremely simple. Hydrogen gas does not act differently upon the muscular elements from oxygen, and atmospheric or rarefied air, or in other words, these different gaseous media do not exert any influence upon the intensity and duration of the muscular current.

It only remained for me to determine precisely the cause of the singular effect exhibited by hydrogen; and as I could not doubt that this effect was owing to the action of hydrogen gas upon the secondary polarities evolved upon the platinum, I tried the following experiment. I introduced a platinum wire into a tube of glass, and with the blow-pipe I soldered it to the upper and closed end of the tube. I constructed a pile of twenty elements, and closed the circuit, as seen in fig. 4. The tube filled with water is inverted in the liquid contained in the extreme cavity of the pile, in which the outer surface of the muscle is immersed. When the circuit was closed the first deflection was 90°, then the needle retrograded as usual. When the deflection was at 20°, I introduced hydrogen into the tube A, and the needle instantly began to rise to 25°, 30°, 40°, 50°. I allowed the hydrogen to escape, filling the tube again with water and closing the circuit, and after ten minutes the needle was at 5°. Again, I filled the tube with hydrogen and the needle rose to 20°, 25°, 30°. Finally, I transferred the hydrogen tube to the other cavity in which the inner surface of the muscle was immersed, and instead of advancing the needle only fell more rapidly.

The effect then of the hydrogen gas is to act upon the oxygen which tends to be evolved upon the platinum which transmits the muscular current, which passes, as is well known in the muscular element itself, from the interior of the muscle to the surface. It is a case analogous to the gas-pile of Grove. These researches seem to prove that the cause of the rapid diminution, both of the muscular and proper current, from the circuit being kept closed, lies in the secondary polarities of the platinum extremities, which generate a current that circulates in a direction contrary to that of the muscular pile. I have yet to mention the experiments attempted by putting the muscular elements in contact with carbonic acid for different lengths of time. I have performed three experiments of this nature, in each of which I have confronted the pile, the muscular elements of which had been in carbonic acid, with another pile similar to the former, but which had merely been left in contact with the air. After having opposed the two piles to one another, I have closed the circuit without ever having found that any difference was induced by the carbonic acid.

Summing up the results of the various and repeated experiments attempted in the view of discovering the influence of some gaseous media (air, air greatly rarefied, oxygen, hydrogen and carbonic acid) upon the intensity and duration of the muscular current, we must conclude that this influence is either null or insensible, or in other words, that the immediate causes of the development of electricity in the muscles reside in the muscular substance, independently of the gaseous medium in which it is placed.

In order better to determine the relation between the signs of the muscular current and the organico-vital conditions of the muscle, since the last few months of the past year I have directed my attention towards ascertaining the intensity of the muscular current generated by a pile of half thighs of frogs, always made up of twenty elements. I did this for the purpose of comparing the influence of the temperature of the medium in which the frogs had lived, with the muscular current which they gave: I will describe once for all and in a few words, my mode of experimenting. From November 1844 to the end of March 1845, I have constantly sent twice a week to have frogs caught from the same marsh. As soon as the frogs arrived at Pisa, they underwent the usual mode of preparation for determining the intensity of their muscular current. A certain number of these same frogs were put into a glass recipient without water, and kept in a little room, the constant temperature of which was +16° C. (60°·8 F.) A similar number of the frogs were placed in a like recipient, but exposed, on the terrace of the meteorological observatory, to the temperature of the atmosphere. Lastly, four frogs taken from the mass were put into the bottle furnished with a tube (fig. 3.), the tube A B of this bottle dipped in mercury. The apparatus thus disposed was likewise left exposed to the temperature of the atmosphere upon the terrace. In eight hours' time the tube C was opened, and inflating the bladder, a portion of the air was collected, and the quantity of carbonic acid produced by the four frogs in that time, and in those given conditions, determined. It is impossible for me to relate all the experiments performed for the space of five months, twice a week; comparing the frogs just arrived fresh from the marshes, with those kept for twelve and twenty-four hours at a temperature of +16° C. I shall merely state some of the numbers given by these experiments, in order to render the results of so many experiments, all concordant, more evident. The temperature of the air, or of the medium in which they live, the activity of the respiratory function, the intensity and duration of the muscular current, are quantities which vary from one another proportionally; the temperature of the medium in which the frog lives cannot be raised without occasioning an increase of activity in its respiration, and a corresponding increase in the intensity and duration of the muscular current.

Four frogs exposed to a temperature varying from 0° to 4°, produced in twenty-four hours 0·5 cubic centimeters of carbonic acid; four other frogs placed in the same recipient and in the same conditions, but at +16° C, gave 0·3 cubic centimeters of carbonic acid. The celebrated experiments of **Edwards** give double this number at a temperature of +27° C. We now come to the signs of the muscular current. In the coldest days of the past winter twenty elements gave a deflection of 32°, then in succession, as the temperature of the air increased, 38°, 48°, 50°, 56°, 60°, 66°. These indications correspond to the gradual increase of the temperature from 0° to 8°. Finally, in the present month, the thermometer rising to +15° in the shade, the intensity of the muscular current was expressed by the numbers 80°, 85°, 90°. It is needless for me to repeat that these numbers refer to the first deviation which takes place on closing the circuit of the pile of twenty half thighs of frogs, always disposed in the same manner, and with their extremities immersed in the two cavities of the board, filled with spring water.

I attained to the same result, comparing the intensity of the muscular current produced by frogs recently caught in the cold season, with that obtained from frogs which had been left for the space of twenty-four hours to forty-eight hours exposed to a temperature of +16° C. The following are some of the many numbers noted down, for the sake of demonstrating, even in this case, the relation between the intensity of the muscular current and the temperature in which the frogs have lived. A pile composed of frogs caught in the coldest part of the season have produced a deflection of 32°. The deflection caused by other similar frogs which were kept for two days in a warmer temperature, was 38°. In another case the muscular current rose from 30° to 48°, in another from 50° to 64°, in another from 66° to 85°.

I would observe, however, that if the frogs are kept too long exposed to a warm temperature, and deprived of the medium in which they generally live and are nourished, instead of the increase of the muscular current, produced by an increase of temperature taking place, a considerable diminution of the current follows in comparison with that of the frogs recently caught. Experience has also shown me (that which was easy to foresee), that in proportion to the elevation of the temperature in the frogs originally, so much the sooner the effect of the want of nutrition was manifest.

I think it important to describe a few experiments which establish the relation between the intensity of the muscular current and the activity of the respiratory function. I have only been enabled to try these experiments upon frogs, from their great tenacity to life. I have repeated the following experiment several times: I skinned ten frogs completely, and put them into a glass recipient near to another in which were ten other frogs intact. The frogs thus flayed live for six, eight, and even ten hours, and are even quite lively. The muscular current produced by the skinned frogs was always considerably weaker than that of the frogs in their natural state. In four experiments made upon the skinned frogs, left in this state from two to eight hours, the first deflections were from 80° to 85°, and the needle first remained stationary at 18°, then continued to fall slowly. In four other experiments made upon frogs in their natural state, the first deflection was 90°, and the needle was stationary at 25°, then fell as usual.

I have performed a few experiments upon the muscular current of warm-blooded animals. In one of these experiments, communicated by M. Dumas to the Academy of Sciences at Paris, and in which I composed the muscular pile, with live pigeons, I succeeded in obtaining the signs of the muscular current. The result of that experiment was to show me that the intensity of this current increased in proportion to the rank the animal operated on occupies in the scale of animals, while the persistence of the current diminished in the same proportion. Operating with great rapidity upon chickens and pigeons, I have been able to demonstrate the truth of this, using for my experiments the thighs of the above-mentioned animals. Comparing an equal number of elements, whether of fowls or pigeons, with the same number of elements taken from frogs, the current, at first, is as intense, and in the greater number of cases more so than that of the frogs. Reflecting a moment on the greater length and resistance of the circuit of the pile of fowls and pigeons, the greater intensity of the muscular current in warm-blooded animals than in frogs, will be manifestly proved. This advantage, however, persists but for a very short space of time: a pile of eight elements of half thighs of pigeons or fowls, at the expiration of an hour, gives either no sign at all, or an almost imperceptible sign of a muscular current in the most delicate galvanometer I possess. This is far from being the case with the same number of half thighs of frogs, which continue for eight hours and more to manifest signs of the same current.

Nor is this difference owing to an unequal evaporation, whether from the internal or external surface of the muscle. I have very frequently bathed the surface of the muscle with pure water, and made a fresh surface, by cutting it away with a razor, and reconstructing the pile: I have never found more than a slight increase in the first deflection, and none whatever on waiting until the needle became fixed.

In order still better to confirm some of my former experiments for showing the influence of the sanguineous circulation upon the intensity and duration of the signs of the muscular current, I compared the current produced by twenty elements, or half thighs of frogs, in their natural state up to the moment of conducting the experiment, with twenty others, from which the heart had been taken away, but which still preserved considerable power of motion for a great length of time; by this means I have established the conclusions to which I had arrived, proving that the muscular current is very much weakened by the defect of the sanguineous circulation. But the following experiment, better than all those referred to formerly, will demonstrate the truth of this last conclusion. From a quantity of frogs all caught in the same pool, I chose twenty, which I put into water that had boiled for two hours. I covered the glass cylinder in which this water was contained, with a plate of glass which I luted to the cylinder. To prevent the water from again taking up air, I covered the surface with oil. The temperature of the water was +15° C. The frogs appeared more vivacious at the commencement of the experiment, from their continual movement from the surface of the water to the bottom, and *vice versâ*, but it was not long before this vivacity ceased, and in about an hour they were all at the bottom of the cylinder, showing signs of suffering, and with but little motion. In two hours all motion entirely ceased and the frogs seemed dead. I have repeated this experiment twice with the same result, the only difference discoverable was in the time, which varies inversely as the temperature of the medium. The signs of the muscular current are considerably weakened in a pile composed from frogs which have been labouring under asphyxia for some time. Thus, while a pile composed of frogs which had not been submitted to any previous injury, caused a first deflection of 90°, and the needle remained fixed between 25° and 30°, with a pile equally composed of twenty elements, but which had been taken from frogs in a state of asphyxia, the first deflection was not more than from 50° to 60°, and the needle stopped at from 10° to 12°. This difference is very striking, and the influence of a normal state of the sanguineous circulation and respiration could not be more clearly demonstrated. I will mention here a singular appearance of the muscles in frogs asphyxiated: the muscles are almost white, and acquire a slightly red tint from exposure to the air. I was desirous to renew and verify the singular action of sulphuretted hydrogen. The following numbers, the result of various experiments, show that the muscular current is very much weakened in frogs killed by this gas. Twenty elements, or half thighs of frogs killed in the usual manner, gave a deflection of 56°. Another twenty elements taken from the same mass gave 44°, another similar pile 41°.

I will now sum up the results obtained from these different experiments. In the first place, the intensity and duration of the muscular current are independent of the nature of the gas which envelopes the muscular pile. Secondly, this current, as I have already shown from the commencement of my researches, is altogether independent of the cerebro-spinal nervous system, and the circumstances which exercise a marked influence upon its intensity are respiration and the sanguineous circulation. Thirdly, those poisons which seem to act directly upon the nervous system, have no influence upon the muscular current; among these I would mention hydrocyanic acid, morphine and strychnine. Fourthly, sulphuretted hydrogen has a marked influence in diminishing the intensity of the muscular current. Fifthly, the intensity of the muscular current varies according to the temperature in which the frogs have lived a certain time; it is needless to observe that this result is not discoverable except in those animals which like the frog necessarily take their temperature from that of the medium in which they live. Sixthly, the intensity of the muscular current increases in proportion to the rank the animals occupy in the scale of beings, while the duration of this current after the death of the animal is in an exactly inverse ratio.

Comparing these conclusions with those generally admitted by physiologists, and drawn from a great number of experiments on the vital properties of muscles, it is impossible not to perceive that the property of the muscles, immediately connected with the muscular current, is that which HALLER calls irritability, and which at the present day I believe physiologists designate by the name of organic contractility, or simply contractility.

With regard to the manner of representing the origin of the muscular current, I only find in my present experiments a confirmation of the opinion I set forth in my preceding ones. The chemical action which goes on in the nutrition of the muscle, principally that which takes place in the contact of the arterial blood with the muscular fibre, is in all probability the source of this electricity in the muscles. I will not here repeat all the many and minute researches, together with the precautions I took, in the numberless experiments attempted in order to exclude every possible cause of a current foreign to the muscle; and nobody who has taken the pains to follow out the description of my experiments, can retain any doubt that the origin of the muscular current is in the muscle endued with a certain degree of vitality. The experiments referred to, making the pile act in vacuum, in hydrogen, in oxygen, and in carbonic acid, prove with full evidence that it is not the action of the gas upon the inner surface of the muscle which occasions the current. To remove all possible doubt, I have taken the precaution of preparing the half thighs of frogs with gilded scissors or with pieces of glass made sharp at the edges; the muscular current was the same, as in fact it ought to have been, as indeed it should have been.

It might be said, reasoning according to a theory the value of which is well-appreciated at the present day, that the cause of the muscular current resides in the contact between the inner and the outer part of the muscle, or in other words, of two heterogeneous bodies. Let this then be the simplest interpretation of all the facts discovered by myself; it is sufficient for me to have well-established that this contact of heterogeneous parts of the muscle generates electricity in the conditions discovered, and such as they are described in the results referred to above.

With regard to my own opinion, it appears more satisfactory to say that the development of electricity takes place in the muscle during life from the chemical action between the arterial blood and the muscular fibre; that the two electric states evolved in the muscle neutralize each other, at the same points from which they are evolved, in the natural conditions of the muscle; and that in the muscular pile imagined by myself, a portion of this electricity is put in circulation just as it would be in a pile composed of acid and alkali, separated from each other by a simply conducting body.

I will conclude this memoir upon the muscular current, with the description of an experiment which appears to me to tend to establish the origin of the muscular current according to these views.

I prepared a great number of little cones, of about the size of half a frog's thigh, cutting the very thin membrane of the cæcum intestine into triangular pieces, and folding them up, and gumming them together upon a little wooden form of a conical shape. When these cones were dry, I prepared some fibrine by beating up some bullock's blood, the bullock being killed at that moment. I immediately fitted the cones with this fibrine steeped in blood, and composed a pile of twenty elements precisely similar to the pile of half thighs. This pile did not exhibit the slightest signs of a current in the most sensible of my galvanometers. Nor is it to be imagined that there was any want of conductibility in the pile just described; in fact, I added four thighs of frogs prepared to the above twenty elements, and I obtained from this pile a deflection but slightly differing from that which the frogs gave, acting alone. This fact evidently proves that simple heterogeneity of the animal parts is not sufficient to produce the muscular current; this heterogeneity should be such as exists in the living muscle.

# XII. *Electro-Physiological Researches.—Second Memoir. On the proper Current of the Frog. By Signor* CARLO MATTEUCCI, *Professor in the University of Pisa, &c. &c. Communicated by* MICHAEL FARADAY, *Esq., F.R.S., &c. &c.*

Received May 7,—Read June 19, 1845.

IN the seventh chapter of my Traité des Phénomènes Electro-Physiologiques des Animaux, after having examined all that GALVANI, HUMBOLDT, VALLI, and more recently NOBILI, have said on this subject, I mentioned all my own researches from which the laws of this phenomenon follow. Comparing the muscular and the proper current together, we find that the influence of the different circumstances affects both currents equally. Thus it is that both the muscular and the proper current vary in the same sense with the variation of the temperature of the medium in which the frogs live. Sulphuretted hydrogen diminishes the proper current just as it does the muscular current. The same may be said of the effects produced upon the proper current by the different degrees of activity of the respiration and of the circulation of the blood. I shall not here mention all the numbers obtained in the experiments recently performed upon the proper current of the frog. I will merely say that I followed up every one of the experiments on the muscular current referred to in this memoir, with another experiment on the proper current, composing the pile with the legs which remained after having prepared the frogs for the muscular current. After so great a number of facts, I do not hesitate in repeating what I have said in page 127 of my Treatise: "comparing one with the other the circumstances which exert an influence over the muscular and over the proper current, they may be said entirely to resemble one another, and that that which increases or weakens the intensity of one of these currents, produces the same effect upon the other." Two points, however, still remain to be cleared up. Do the circumstances which affect these two currents operate upon both in a like degree? or in other words, does that circumstance which diminishes as well the muscular as the proper current of the frog, act proportionally in that diminution?

I had found in my first experiments, that comparing two piles, one consisting of half thighs of frogs, the other of entire or halves of frogs, so as to obtain the proper current, the signs produced by the latter pile continued longer than those evinced by the muscular pile.

I then began to renew my former experiments for the purpose of convincing myself of the reality of this difference, the only one between the muscular and the proper current.

Studying afresh the influence of the various circumstances (temperature, respiration, sanguineous circulation, sulphuretted hydrogen) upon the proper current compared with the muscular current, I came to the following conclusion: the diminution which occurs in the intensity and duration of the proper current, from the decrease of temperature, from defect of respiration and the sanguineous circulation, and from the action of sulphuretted hydrogen, is considerably greater than that which takes place in the intensity and duration of the muscular current. Thus, with the same number of elements, I have always seen that the proper current has been considerably weaker than the muscular current, operating on frogs asphyxiated, killed with sulphuretted hydrogen, or in the coldest weather. This difference decreases in proportion to the robustness and vivacity of the frog, so that in the spring and summer, choosing very strong frogs, the signs of intensity and the duration of the proper current equal and even surpass those of the muscular current.

I was desirous of again studying the proper current in piles composed either of legs alone or of half thighs of frogs, or of entire frogs (figs. 5. 7. 8). In general, as I found before in my former experiments, these three piles produced currents the intensity of which was sensibly alike in all. This coincidence seems at first rather singular, considering the diversity of the internal resistance of the three piles, and admitting that the electro-motor element of the proper current resides in the leg alone. The experiments which I shall report at the close of this memoir, explain this fact sufficiently clearly.

Comparing, however, the three above-mentioned piles, composed from frogs which had been exposed previously to the action of debilitating causes, I have always found that the signs of the proper current, in the pile composed of the legs alone, somewhat exceeded those of the other piles.

I would here refer to another experiment, described at page 116 of my Treatise, performed with a pile (fig. 6.) of half frogs, from which the upper half of the thigh had been taken away. In this pile the proper current is in opposition to the muscular current, for which reason the current obtained is very weak, and sometimes null. I have still, however, constantly observed that if the frogs employed for this experiment are very robust, and in those conditions which we have seen to be favourable to the proper current, the signs of a current which this pile gives, though always very weak, are in favour of the proper current; while, on the contrary, when the frogs are taken in the conditions unfavourable to the proper current, the slight current which this pile gives are in favour of the muscular current.

From the sum of these facts I am again forced to conclude, as I was led by my former experiments to do, that the proper and the muscular current are in general subjected to the same laws, and that both these currents vary in the same sense, under the same circumstances.

But why should the proper current belong exclusively to the frog? This is the problem the solution of which I had long been anxious to arrive at, and hope finally to have given a satisfactory explanation.

I had frequently observed, while operating with great rapidity upon rabbits, fowls, and pigeons, that the signs of the proper contractions frequently manifested themselves, and that therefore the celebrated experiment of Galvani was repeated in warm-blooded animals. When the thighs are cut away from these animals, the nerve laid bare, and folded back upon the leg, contraction is frequently visible. These contractions are more constantly obtained by composing piles of these thighs and making the nerve touch the leg. I must say, however, that every time that I have composed a pile of such thighs, I have obtained the signs of the muscular current, for which reason the contractions might have been attributable to that current.

Let it be remembered, however, that in composing these piles, it is impossible not to put the current which parts from the internal surface of the muscle in circulation, for which reason a pile should be made analogous to that of the half frogs divided at the upper half of the thigh (fig. 6.). Observation has shown, from the time of Galvani, that the points of the leg of the frog to be touched, for the purpose of producing the proper contraction, are the points of insertion of the surface of the funicular tendon of the gemellus or gastrocnemius muscle into the calcaneum.

In one experiment, described at page 105, I had endeavoured to remove the tendinous surface of the muscles of the legs, then composing the pile with the frogs so prepared, I had the current as at first, that is, directed from the feet to the head, in the animal. This experiment, however, did not prove that the proper current exists independently of the tendinous surface of the muscle; in fact, removing the tendon, I lay bare the muscle, and so doing prepare a muscular pile, in which the current, being directed from the interior to the exterior of the muscle, is therefore in the same direction as the proper current.

The following are the experiments which led me to generalize the fact of the proper current of the frog. There is no difficulty in preparing the gemellus or gastrocnemius muscle of the frog, leaving a certain portion of the funicular tendon, or tendo Achillis, which goes on to insert itself into the calcaneum, and taking care to avoid as far as is possible injuring the upper part of the muscle. I prepared a great number of these elements, and arranged them in a pile, as represented in Plate IV. fig. 9, in such a manner that the tendinous extremity came in contact with the belly of the muscle. From this pile I obtained signs of a current directed in the muscle from the tendon to the muscle, that is to say, in the same direction as the proper current. Comparing together an equal number of elements arranged in piles, and consisting of legs alone, or of gastrocnemius muscles only, the intensity of the current has been to all appearance the same.

With equal facility the rectus femoris of the frog may be prepared, leaving the tendinous extremity which is inserted into the patella, and laying bare as little as possible of the internal muscular surface of the upper part. Thus I have been enabled to form a pile composed of several recti femoris, always arranging them in such a manner that the tendinous extremity reposed upon the surface of the muscle as far removed as possible from the internal part. A pile so formed has given constant and distinct signs of a current directed in the muscle from the tendon to the muscle. With regard to the intensity, I must add that the signs have always been weaker, from the pile composed of recti femoris, than those from the pile of half legs or gastrocnemii muscles.

It is very natural that the cause of this difference should be owing to the fact of the muscular current circulating in a contrary direction to the other. And, in truth, if the disposition of the elements which compose these piles be ever so little changed, so that the tendon of one of these elements be made to repose upon or near to the interior of the muscle, the signs of every current become very weak or cease altogether (fig. 10.).

I have prepared a number of anterior cubital muscles, or muscles of the fore-arm of frogs, which likewise have at their extremities, near the carpus, a very distinct tendinous band. A pile composed of these muscles, disposing them as usual, with the tendon resting on the muscular surface of the next element, gives constant and very distinct signs of a current, the direction of which, in the muscle, is from the tendon to the muscle. The following in the meanwhile is the generalization of the fact of the proper current of the frog: the current is directed within the muscle from the tendon to the superficies.

It remained for me to extend this fact to its operation upon the muscles of warm-blooded animals, and the experiments accorded in such a manner as to leave no possible doubt.

In these experiments I employed fowls, pigeons, rabbits and dogs. It is necessary to operate with great rapidity upon these animals, since, as in the muscular current, the signs of the current which we are now studying cease very quickly. Not less than six or eight elements are necessary for eliciting signs of this current sufficiently evident to remove all doubt. In all these animals the muscular extremities turned towards the feet are furnished with tendons much more distinct and grouped together than those of the upper and opposite extremities. I wished at first to have separated the different muscles as I had done those of the frogs, but the process is much more difficult with the muscles of these animals, which always get considerably lacerated.

In order to succeed in the best possible manner, after having removed the integuments, I cut the thigh as near as possible to the articulation with the os ilium; and in pigeons it is easy to tear the thigh out of the socket. The surface of these elements should be well-dried and the pile formed (fig. 11.), disposing them in such a manner that the inferior extremity of the leg, where the tendons unite together, reposes upon the surface of the muscular masses of the leg. In this manner the muscles of the thigh have no part in the circuit. From similar dispositions of eight elements taken from rabbits or pigeons, the signs of a current, marked by my galvanometer, were from 12° to 15°, and 20°, and directed in the pile from the tendinous extremities to the muscular surfaces. It is sufficient to introduce the thighs into this pile, to put, that is to say, the interior of the muscle in contact with the tendinous extremity, for the sign of the current to be inverted, and the muscular current produced (fig. 12.). This proves how necessary it is, in order to have the signs of the current directed from the tendon to the muscle, not to comprehend any portion of the interior of the muscle in the circuit.

Let us then conclude, that "touching a mass of muscle belonging to a living animal, or an animal recently killed, with a homogeneous conducting arch, one extremity of which is contact with the tendon of the muscle, and the other with the superficies of the muscle itself, signs of an electric current are obtained, which circulates in the muscular mass, its direction being from the tendon to the external surface of the muscle."

This fact comprehends that of the proper current of the frog.

Let it not be forgotten that from the sum of all our researches, it has been proved that both the muscular and proper current are subject to the same laws, and thus in all probability have a common origin. I would here again call the attention of anatomists to the study of the structure of the muscles, and of the relation which exists between the muscular fibres, the tendon, and the membrane which invests the fibres or the sarcolemma.

If I have rightly understood the classical labours of my friend Mr. Bowman, it would follow that the extremities of the elementary muscular fibres are immediately connected and continued with the tendinous fibre; while the sarcolemma which invests the muscular fibre ceases abruptly where the tendon begins. On the strength of this disposition I cannot abstain from emitting an hypothesis upon the origin of the proper current, which would reduce all that we know on the subject of animal electricity to one principle alone. Let it be granted that the tendinous fibre, from its structure, from its connections with the muscular fibre, and from its conductibility, represents the internal part of the muscle, and that the sarcolemma, on the contrary, is distinguished under this aspect from the muscular fibre; then the case of the proper current, or of the current from the tendon to the muscular surface, becomes at once the simplest and most general case of the muscular current. We must never forget the analogy between the muscular electro-motor element and the Voltanian element: the zinc is represented by the discs of the muscular fibre, the acid liquid by the blood, the platinum by the sarcolemma. Whatever be the conducting body with which the zinc is made to communicate with the platinum, the current is always in the same direction. If it be well proved by anatomy that the tendinous extremities are continuous with the extremities of the muscular fibres, and that the sarcolemma which envelopes the muscular fibre alone, and not the tendon, is not continuous, is not as it were identified with the muscular fibre, the analogy between the muscular element and that of Volta is complete and perfect.

The chemical actions of nutrition evolve electricity.

*Pisa, April* 7, 1845.

to the muscular surfaces. It is sufficient to introduce the liquids into this pile, in pus, that is to say, the interior of the muscle in contact with the tendinous extremities, for the sign of the current to be reversed, and the muscular current produced (fig. 15). This proves how necessary it is in order to have the signs of the current derived from the tendon to the muscle, not to comprehend any portion of the interior of the muscle in the circuit.

Let us then conclude, that "touching a mass of muscle belonging to a living animal, or an animal recently killed, with a homogeneous conducting body, one extremity of which is in contact with the tendon of the muscle, and the other with the surface of the muscle itself, signs of an electric current are obtained, which circulates in the muscular mass, its direction being from the tendon to the external surface of the muscle."

This fact completes that of the proper current of the frog.

Let it not be forgotten that from the sum of all our experiments it has been proved that both the muscular and proper currents are subject to the same laws, and that in all probability they have a common origin. I would here direct the attention of physiologists to the study of the structure of the muscular fibre and the relation which exists between the muscular fibre, the tendon, and the [illegible] with which it covers, the [illegible] of the sarcolemma.

If I have rightly understood the admirable labours of Mr. [illegible], it would follow that the extremities of the [illegible] are [illegible] connected and continued with the tendinous [illegible] the muscular fibre [illegible] the [illegible] of the current, which would [illegible] [illegible] the internal part of the muscle [illegible] [illegible] analogy between the muscular electro-motor element and the Voltaic element [illegible] represented by the [illegible] of the [illegible] which the wire is made to communicate with the interior of the muscle [illegible] the same direction. If it be well proved by anatomists that the tendinous [illegible] are continuous with the [illegible] of the [illegible], and that the sarcolemma which envelopes the muscular fibre [illegible] analogy [illegible] and that of Volta is complete and perfect.

The [illegible]

Pisa, April 7, 1848.

# XIII. *Electro-Physiological Researches.—Third Memoir. On Induced Contractions.*

*By Signor* Carlo Matteucci, *Professor in the University of Pisa, &c. &c.*

*Communicated by* W. Bowman, *Esq., F.R.S.*

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THE term *Induced* contractions was applied in England to a physiological fact discovered by myself, and described in the tenth chapter of my treatise on the Electro-physiological Phenomena of Animals. I shall henceforth adopt this denomination, since it has the advantage of expressing the phenomenon with brevity, and, to a certain degree, its nature.

I will begin by explaining, in a few words, in what this fact consists, together with the principal researches which I made in the commencement for the purpose of discovering its laws. Having prepared a galvanoscopic frog, I laid its nerve upon one or both the thighs of a frog prepared in the ordinary manner; this done, on applying the poles of a pile upon the lumbar plexuses of the frog, at the same time that the muscles of the thighs were contracted, contractions were excited in the galvanoscopic leg, the nerve of which reposed upon the thigh of the other frog. I discovered the same fact, placing the nerve of the galvanoscopic frog upon a muscle of the thigh of a rabbit, and exciting the muscle to contraction by means of a current which traverses its nerve. I have even seen contractions of the galvanoscopic frog occur without applying the electric current for the purpose of contracting the muscle which ought to induce the contractions, adopting for this purpose any other stimulus to the lumbar plexuses or to the spinal marrow. I finally tried these experiments, introducing between the nerve of the galvanoscopic frog and the inducing muscular surface very fine laminæ of different substances. A leaf of gold and a very fine non-conducting stratum of mica or of glazed paper being interposed prevented the phenomenon, that is to say, the induced contractions in the galvanoscopic frog failed to appear, whilst a stratum of fine paper soaked in water did not interrupt the induced contraction. From the whole of these facts I was led to conclude,—1st, that the contraction induced in the galvanoscopic frog could not be attributed to the effect of derived currents; 2nd, that it should rather be considered the effect of an electric discharge taking place during the contraction of a muscle. For the sake of supporting this explanation of the induced contractions by facts, I instituted a great number of experiments which are described in the tenth chapter above referred to. With this view I composed a pile of entire frogs, and closed the circuit with the two extremities of the galvanometer. Allowing the needle to become stationary, I touched specially the nerves of the frogs composing the pile with a solution of potassa, by which means contractions were excited in these frogs. Operating in this manner, I have often remarked the deflection of the needle to be increased by a few degrees, after which the needle retrograded. When the frogs were touched several times with the potassa, or were very much weakened, so that touching them again with the alkali no longer produced contractions, it has, in most cases, occurred that there was no sign of increased deflection in the needle of the galvanometer. Finally, bathing the nerves of frogs arranged in piles with acid or saline solutions, the deflection, far from increasing, rapidly diminished, at least in the beginning.

These facts, with which I paused, might have appeared in some manner favourable to the idea that the induced contractions were the effect of an electric discharge which accompanies the act of muscular contraction: notwithstanding this I terminated the chapter referred to with the following words:—"I cannot take upon me to affirm that the question is entirely solved, and I pause here from not knowing how or by what way to advance to solve it."

The importance, however, of the fact of induced contractions thus always appeared to me very great, and consequently I have not failed to give my strictest attention to the study of it, and I have reason to believe, latterly, with some success. I shall, therefore minutely describe in this memoir all the experiments that I have instituted upon the induced contractions, and I trust the reader will excuse the prolixity of the description.

Before commencing a fresh series of investigations into the fundamental fact of the induced contractions, I thought it necessary to repeat and vary the experiments of which I have already given an outline, and which were directed to the purpose of discovering whether there is a development of electricity during the contraction of a muscle. In order to have a more fixed and considerable deflection, it was necessary to employ piles consisting of a greater number of elements than those I had made use of previously. I imagined that for this purpose a muscular pile would be far preferable to a pile of frogs. I avail myself of this opportunity of referring to an experiment made for the purpose of proving the existence of the muscular current in the living human subject. I applied the nerve of the galvanoscopic frog with care to the muscle of a leg laid bare by a wound. The most lively contractions were excited in the galvanoscopic frog every time that the circuit was suitably closed between the interior of the wound and the surface.

My late experiments have shown beyond all doubt that, the number of elements taken from the same frogs being equal, the muscular current is much stronger than the proper current. I have recently shown that when from defect of nutrition, a very low temperature, or the action of sulphuretted hydrogen, &c., both the muscular and the proper current of the frog are weakened, the diminution is much more considerable in the latter than in the former. And in fact, composing the pile described at p. 116 of my treatise with halves of frogs prepared by cutting the thighs in half, I find a differential current varying in intensity, but always in the direction of the muscular current. It is only in very robust frogs, dividing the thigh in the thickest part, and leaving a very small internal surface of the muscle exposed, that the differential current is found to be either null, or in the direction of the proper current. This fact attracted my attention in the course of my early experiments, but the explanation of it is clearer to me since my later investigations, reflecting that in leaving the thigh almost entire, we have two elements, that is to say, the muscles of the leg, and those of the thigh, which direct the current in the same direction, while there is but one element of the muscular current which gives a current in a contrary direction.

Returning to the subject of this memoir, I would observe that I have employed a muscular pile in the view of determining whether there is evolution of electricity in the contraction of a muscle. But since in order to excite the contractions of the muscle, I was obliged to bathe it with concentrated saline or acid solutions, or better with alkaline solutions, I previously studied the effects of the action of these liquids upon the muscular current. In this view, from a great number of frogs I selected eight which I prepared in the usual manner, and which furnished sixteen elements or half thighs. Closing the circuit, the needle reached 90° and remained stationary at 22°. Constructing another similar pile, after having well-washed and then dried the sixteen half thighs, the result was the same. Another sixteen similar elements were immersed for a few seconds in a diluted solution of sulphuric acid, and afterwards washed several times in water, so that they did not redden turnsol paper. Composing the pile and closing the circuit, a current was produced in the direction of the muscular current, but the deflection was only 6° or 7° at first, and the needle was fixed at 0°. I rapidly cut the half thighs with a pair of scissors so as to renew the internal surface of the muscle in a fresh state. Recomposing the pile, the current was still weaker than that indicated above. Thinking that the effect of the acid solution upon the muscular elements was to diminish the conductibility, I constructed a muscular pile of eight half thighs of frogs taken from frogs previously intact, to which I added four entire thighs taken from frogs likewise intact: the current which resulted was 46°. In the room of the four entire thighs, I next substituted four entire thighs which had been immersed in sulphuric acid and then washed, the current was 44°. The conducting power therefore had not varied in the muscular masses subjected to the action of the acid solution. To be still more certain of this conclusion, I tried the experiment already described, substituting eight half thighs for the four entire ones for the purpose of prolonging the circuit. These eight half thighs being treated with the acid solution, and joined together by contact of the internal surface of one with the external surface of the other, the result was the same.

I next repeated the same experiments, using a sufficiently concentrated solution of potassa in which to immerse, for a few seconds, the muscular elements or half thighs. These elements were then washed in pure water until they showed no alkaline reaction. Composing the pile with sixteen elements, and closing the circuit, there was a first deflection of from 10° to 12° in the usual direction of the muscular current, and an imperceptible stationary deviation. Making a fresh section of the muscle and recomposing the pile, the result was the same. And in this case, likewise, the conductibility was not changed; consequently the alkaline or acid solutions act as I had before found water act at a high temperature. I will here repeat an experiment which I made, merely to show its accordance with those related above. Sixteen half thighs of frogs were immersed for a few seconds in water at about 50° C. On taking these elements out of the warm water and bathing them with cold water, I constructed a pile, closed the circuit, and had a first deflection of 12° in the direction of the muscular current, and the needle stopped at 0°. After having renewed the internal surface of the muscle by making a fresh section, I recomposed the pile, and the signs of the current were the same as before. And also in this case I assured myself of the fact, that the conductibility had not been sensibly changed by the action of the hot water. I will add, moreover, that it is not to the repeated washing in pure water at the ordinary temperature, that the diminution in the intensity of the muscular current is to be attributed. I have very frequently seen the same deflection slightly varying in intensity, produced by a pile of a given number of elements, or half thighs, sometimes washed in pure water, at others not washed at all. Even a solution of chloride of sodium highly concentrated, is capable of diminishing considerably the signs of the current produced by a pile of which the elements have been immersed for some seconds. Thus, whilst sixteen common elements produce a first deflection which mounts to 90°, and remains fixed at from 20° to 22°, if these elements be left for a few seconds in the saturated solution of the sal marinus and then taken out, the first deflection is about 60°, and the needle becomes stationary at between 8° and 10°.

We are thus led to conclude, that by the action of the alkaline acid or saline solutions in a concentrated state, those conditions of the muscular elements by which the evolution of electricity takes place, are destroyed. Nor is this conclusion in opposition to the admitted origin of this current: but since by the action of the acid, or saline solutions, the signs of the muscular current either cease or are greatly weakened, it remains to be explained why, in the experiments reported in my work, and of which I have given an outline in the commencement of this memoir, the diminution of the current did not take place on touching the elements of a pile of frogs with an alkaline solution, while it occurred immediately on touching them with an acid solution.

On the contrary, we have observed, that operating with alkalies, at the first contractions that are excited, there is in many cases a perceptible increase of deflection, which lasts for some seconds. With acids, on the contrary, the deviation is lessened immediately, and returns again after a short time.

Before endeavouring to account for these phenomena, I will describe those of my experiments performed with the greatest exactitude, in the view of ascertaining whether there be in contraction any evolution of electricity. I prepared a great number of frogs according to GALVANI's method; I then cut their legs, disarticulating them as well as I was able: there remained a couple of thighs united by a portion of the spinal chord. One of these thighs I cut in half, and in this manner I had a certain number of elements all alike and consisting of an entire thigh, a portion of the spinal chord, and a half thigh. It is easy to understand how, with these elements, I composed a muscular pile, that is to say, applying the external surface of the entire thigh upon the internal surface of the thigh of the succeeding element (fig. 13.). This done, I immerse the extremities of the galvanometer in the liquid in which the extremities of this pile terminate. A small appendage to the extremities of the conducting wires of the galvanometer, precludes the necessity of my holding the latter with my hands when I require to complete the circle. I have repeated this experiment a great number of times, at one time using a pile of twelve, at another of sixteen, at other times of twenty elements. Both the first deflection, and that at which the needle remained stationary, were somewhat weaker than they would have been had the piles been composed of an equal number of halves of thighs only. This difference is mainly attributable to the greater length or resistance of the circuit. In every case referred to above, after having suffered the needle to become stationary, which it did in the various experiments at 10°, 12°, and sometimes 15°, I touched the lumbar plexuses of the different elements with a sufficiently concentrated solution of potassa, excepting, however, the two extreme elements, for fear the alkaline solution should reach the liquid in which the extremities of the conducting wire of the galvanometer were immersed. The muscular contractions took place immediately upon the application of the alkali, and lasted for some seconds without ever being sufficiently strong to interrupt the pile by displacing the elements. During these contractions the needle of the galvanometer did not move. In some cases I have seen the needle go back, in others rise to 2° or 3°. But these variations are too uncertain in the greater number of cases, and most generally correspond to a too sudden motion of the elements of the pile which disturbs their contact.

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Let us then conclude that direct experiment answers negatively to the question we proposed to solve, whether there were evolution of electricity in muscular contraction.

Having got rid of this part of the question, the next which presents itself is the consideration of the phenomena which we observe in the proper current (for which we employ whole frogs), and which consist in signs of increased intensity on first touching the lumbar plexuses of the frogs with potassa, while, on the contrary, an acid solution causes the needle to fall instantaneously. To arrive at a knowledge of these facts I have repeated and varied my former experiments, and the explanation of the facts is as follows:—

Whatever be the form of the elements used for constructing the muscular pile, that is to say, whether it be made of entire frogs, of halves of thighs, or, as described (fig. 13.), if the surface of the muscular elements be bathed with an acid or alkaline solution, it constantly happens, whether there be contractions or not, that the deflection diminishes and the needle returns to zero, where it remains if the action of the alkali be repeated, or the solution too concentrated. This effect is identical with that already described, which occurs in the muscular elements immersed for a few seconds in acid or alkaline solutions. In the manner of conducting the experiment (fig. 13.) which we have adopted, in order to excite the muscles to contraction, we touch with the alkali such points of the muscles as are in a certain manner out of the circuit, and which certainly do not constitute the electromotor part of the element. In the pile of entire frogs, with which we succeed oftenest in obtaining signs of increase of the current for a few seconds, on touching the lumbar plexuses alone with the alkali, these signs of increased intensity never occur if the entire muscular surface be bathed with an alkaline solution. I will add, moreover, that if an acid solution be employed, and care be taken to touch the lumbar plexuses only with a paint-brush, carefully avoiding the muscles of the thighs or legs, the deflection is not diminished, and in spite of the contractions which are excited, although these are less than those which the alkali occasions applied upon the muscles, there is no increased deflection. The surface of the muscle must be touched with the acid to make the needle fall. The same occurs with the alkali, and is, I repeat, in accordance with the experiments already referred to with the muscular elements which have been immersed in the acid or alkaline solutions.

It is then only with the pile of entire frogs, and only when the lumbar plexuses of these alone are touched with the alkali, that sometimes a slight increase of deflection is perceived, while this does not occur when acids are similarly applied. Taking up our ground upon the strength of all the experiments described above, it is impossible to consider this result as contrary to the absolute answer in the negative given above to the question whether there were development of electricity in muscular contraction.

In the course of the present memoir other irrefragable proofs will be adduced in support of the assertion to the contrary. It is impossible for anybody who looks well to the whole of these phenomena, not to perceive the difficulty which occurs in endeavouring to explain why, in the particular case described above, the alkali should produce an increase of deflection in the proper current of the pile of entire frogs. For myself, I incline to the belief that stronger and more permanent contractions being excited by the alkali than by acids, the contact between one element and the other becomes thereby more intimately established in the greater number of cases, and, by that means, the internal conducting power is increased. In effect, this contact is very imperfectly established in the pile of entire frogs, and very great difference in the intensity of the current is perceptible with the same elements by improving their mutual contact.

Whatever may be the right interpretation of the slight increase which occurs in the intensity of the proper current, on touching the lumbar plexuses of the frogs, and thus exciting muscular contractions, certainly this fact alone is insufficient to lead us to admit the evolution of electricity during muscular contraction, while, as certainly, all the other cases described oblige us to conclude the contrary.

I will now proceed to detail several other new researches upon the phenomenon of induced contractions: but I must first entreat that the reader will excuse my trespassing on his time with a lengthened account of my numerous experiments: the fact of induced contractions is certainly of such importance, and at the same time so obscure, that it cannot be established except by long and patient researches.

No one who has once seen induced contractions occasioned by contractions excited by other means than an electric current, can hesitate to admit that this current is not the direct cause which produces them.

If the nerve of the galvanoscopic frog be applied upon the muscles of the thigh of a frog prepared in the ordinary manner, and the spinal chord be suddenly lacerated with scissors, or with the broken edge of a piece of glass, or by any other means, induced contractions very rarely fail to occur. It is however certain that passing an electric current through the lumbar plexuses, the phenomenon of induced contractions scarcely ever fails.

As I have most frequently resorted to the passage of the electric current for exciting contractions, I have taken every possible precaution to prevent any portion of the electric current from invading the galvanoscopic frog or the thighs of the entire frog. The best mode of conducting the experiment, and the way which offers the best chance of success, is to fill a common dinner-plate with Venice turpentine and spread the frog upon it. It is hardly necessary to say that the turpentine should be so dense that the frog cannot sink in it; care must be had in preparing the galvanoscopic frog not to leave any portion of muscle attached to the nerve.

Whatever may be the position of the nerve of the galvanoscopic frog relatively to the muscular fibres of the thigh on which it is laid, the phenomenon of the induced contractions always continues. Thus on some occasions I have extended this nerve parallel to the muscular fibres, or I have extended it normally to the said fibres, or in fine, I have bent it in a zigzag, that is, in all directions, and the induced contractions have been obtained in every case and without sensible difference.

These induced contractions are obtained by applying the nerve of the galvanoscopic frog on the gastrocnemius muscle of the leg.

I have also attempted, by washing the galvanoscopic frog several times in pure water, to remove any trace of blood or other humours which might be sprinkled over the surface of its muscles, and the induced contractions have equally continued.

I have cut with a razor, or better still with a pair of scissors, the surface of the muscles; I have then placed the nerve of the galvanoscopic frog upon the cut surface only of the muscles themselves; the induced contraction has taken place. It has also occurred on disposing the nerve of the galvanoscopic frog upon the muscle so that the extremity of the nerve should fold back over the nerve itself, and thus form a kind of closed circuit.

I have also wished to ascertain if the induced contractions continued even when the nerve of the galvanoscopic frog had not been cut. I have therefore prepared the frog, so as to preserve the nerve entire, as follows. Having skinned a frog I remove the viscera, then the bones and muscles of the pelvis, and finally the muscles of the thigh, taking care to preserve the nerve of the thigh. In this manner I obtain a frog whose nervous system is entire, and which has a long nervous filament uncovered, that is, the lumbar plexus and the nerve of the thigh. Having thus obtained the frog, I prepare another in the ordinary manner, which I place upon the turpentine in the manner already described. Then I place the nerve of the frog, prepared as has been said, upon the thighs of the other frog (fig. 14.). On exciting the muscular contractions, the induced contractions are obtained as they are by using the galvanoscopic frog alone; and at the same time the contractions in the muscles of the back and in the other leg are obtained. We shall have occasion to recur to this experiment further on; we now limit ourselves to deduce from it that the induced contractions are obtained, even when the nerve placed upon the muscles in contraction is entire.

In using the frog thus prepared, I have experimented upon the induced contractions, by causing the nerve that is in contact with the muscle in contraction to be already in some manner excited by a current or some stimulus. For this purpose I have comprehended the galvanoscopic frog in the circuit of a voltaic circle, or have applied upon the nerve a drop of an alkaline solution. Every time that the inducing muscles are contracted, there is always induced contraction, whether the nerve through which this current is transmitted be already excited or not, and consequently, even when the muscles in which the induced contractions are generated, are already in contraction; and, in fact, in spite of the contraction already present there is no difficulty in perceiving the induced contraction that follows.

Many easy experiments may be made to prove that in whatever way the nerve of the inducing muscle be excited, if its contraction fail, the induced contraction is also wanting. I shall limit myself to reporting some of the principal ones. Having cut the nerves at two or three points in the interior of the inducing muscle, so as to prevent its contracting, the induced contraction is wanting when the nerve is in any way stimulated external to the inducing muscle.

If, without cutting the nerve, all the tendinous extremities of the muscles of the thigh are severed, and transverse cuts are also made in those muscles, taking care not to divide the nerves, on stimulating them, the inducing and also the induced contractions are wanting.

By removing with care all the muscles of the leg of a frog, the nervous filament that runs in the leg itself may be uncovered. This nerve may be irritated either with the current or any other stimulus, after having extended the nerve of the galvanoscopic frog upon the muscles of the thigh above. These muscles of the thigh do not contract; the induced contraction is wanting.

By operating upon rabbits or upon dogs, I have been able, with the electric current, to act upon the nervous filaments that run to the kidneys, to the stomach, and to the intestines: when the nerve of the galvanoscopic frog was extended upon the different parts in the same conditions as for the muscles, I never obtained any sign of induced contraction.

I have also sought to discover if there was contraction induced by applying the nerve of the galvanoscopic frog upon the excited nerve. For this purpose it is sufficient to prepare two galvanoscopic frogs, and to extend the nerve of the one upon the nerve of the other, in the points nearest to the leg. To perform the experiment with every care, the two frogs are disposed upon turpentine. Then, either with the current or with some other stimulant, the superior points of the nerve of the frog, that I shall continue to call inducing, are erected. There is no induced contraction in the galvanoscopic frog, although this contraction immediately occurs, if its nerve is extended over the gastrocnemius of the other. It is needless to say that in using the current to excite the inducing contraction we must never place either of the electrodes of the pile in contact, or in proximity to the nerve of the galvanoscopic frog.

It is proved by the above experiment that an excited nerve, and one in which is certainly propagated that cause, whatsoever it be, which awakens contraction in the muscle and sensation in the brain, does not act upon the nerve of the galvanoscopic frog placed in contact with it. I will also add the following experiment. I have uncovered the brain of a frog prepared in the ordinary method with the greatest possible care, and I have extended upon it the nerve of the galvanoscopic frog.

In various experiments thus tried, I have applied the current sometimes direct, sometimes inverse, upon the lumbar plexuses, and in others I have touched these plexuses with potassa, and I always obtain the contractions in the lower limbs and convulsions in the back. However, I have never found signs of induced contractions in the galvanoscopic frog that was extended upon the brain. The induced contractions are therefore originated solely by the muscle in contraction.

I have sought to discover how these induced contractions grow weak, by causing them to be originated by means of a muscle whose own contraction was induced. In a word, I have examined the induced contractions of the second and third order, &c. For this purpose I prepare various galvanoscopic frogs, and one in the ordinary manner, and I dispose them in the following way. Upon the muscles of the thighs of the entire frog I extend the nerve of a galvanoscopic frog: upon the gastrocnemius of this, I extend the nerve of another galvanoscopic frog, and so on in succession. The whole is placed upon turpentine. On exciting the contractions of the entire frog by making the current pass through its lumbar plexuses, I have seen in many instances *three* galvanoscopic frogs contract, and all with nearly the same vivacity. The contractions are never wanting in two frogs, but I have never been able to perceive four contracted. There is therefore an induced contraction of the first, the second, and the third rank. Before coming to the consequences to be drawn from the above-mentioned facts, it remains to me to describe the many experiments I have made for the purpose of discovering the influence of bodies interposed between the muscle in contraction and the nerve of the galvanoscopic frog upon the induced contraction. From my first experiments upon the induced contraction, I had perceived that on extending a sheet of gold leaf, such as is used for gilding, upon the muscle, and then placing the nerve of the galvanoscopic frog upon the gilded muscle, the induced contraction did not take place. That this should happen, it was necessary that the muscle should be completely coated with the gold leaf, which is not the case after one or two contractions when the gold leaf gets torn. I had then seen that a varnished paper (*papier glacé*) interposed between the muscle and the nerve impeded the induced contraction; and lastly, a sheet of felt soaked with water or the serous liquid that bathes the surface of muscles, and interposed between the muscle and the nerve of the galvanoscopic frog, does not prevent the induced contractions. Our knowledge was limited to these three cases relative to the action of interposed bodies upon the induced contraction. I have therefore sought to extend and vary the experiments. The manner of operating that I have adopted, consists in preparing a frog in GALVANI's method and placing it upon turpentine; while an assistant is preparing more galvanoscopic frogs whose nerves I extend upon the muscles of the thighs of the first frog. In order to awaken the inducing contraction, I always use a small FARADAY's pile of fifteen elements immersed in pure water, and whose electrodes are covered with silk and varnished.

There is no liquid body among the many examined that impedes the induced contraction; pure water, slightly acidulated and saline water, serum, blood, olive oil, diluted alcohol, the varnish of alcohol and resin, volatile oil of turpentine are the liquids made use of in these experiments, and through which the induced contraction takes place. I am always accustomed to let some drops of the liquid under experiment fall upon the muscle, and to dip the nerve of the galvanoscopic frog in the same liquid. The induced contraction still subsists even if a thin sheet of felt imbued with the above-mentioned liquids is interposed between the muscle and the nerve.

The slight conductibility of some of the liquids made use of (oil, oil of turpentine, varnish, &c.) has made me doubt whether the induced contraction would not subsist even in spite of the interposition of an absolutely insulating body. I assured myself, in fact, that across a layer, even very thin, of the said liquids, neither the muscular current nor the proper one was propagated. On holding the galvanoscopic frog in the hand, and causing its nerve to come into contact with a wetted paper that in any manner communicates with the ground, the contraction, as is well-known, is obtained. The same thing happens on touching with the nerve of the galvanoscopic frog, the muscles either of a frog or of any other animal in communication with the earth. In all these cases it is always the proper current that circulates through the observer, the ground, the touched body, and the galvanoscopic frog. Now if we wet the nerve of the galvanoscopic frog either in common oil, or in oil of turpentine, or in varnish, the thin stratum that adheres to the muscle is sufficient to impede the circulation of the proper current.

It is therefore indubitable that if an induced contraction is propagated through a stratum of the bad conductors mentioned, this induced contraction cannot possibly be owing to a current generated in the contracting muscle, and passing thence into the nerve of the galvanoscopic frog.

Nevertheless these experiments were so important for the theory of the phenomenon of induced contraction, that I desired to try the effect of interposing between the contracting muscle, and the nerve of the galvanoscopic frog, a still worse conducting body than those mentioned. The body that has served me in these experiments has been Venice turpentine nearly solid, and rendered more or less liquid by adding to it a little volatile oil of turpentine. Having smeared over the thigh of a frog with this mixture, and wetted the nerve of a galvanoscopic frog with it, I prepare the experiment as usual, and the induced contraction continues. To prove the bad conducting powers of the mixture made use of, I hasten to say, that if I apply one pole of the pile with which I excite the contractions upon the stratum of the insulating mixture, of course without penetrating to the muscle, and I touch with the other pole the nerve of the galvanoscopic frog, the contractions are not excited in it. It is therefore proved from this experiment that the induced contraction propagates itself through a stratum of an insulating substance that prevents the propagation not only of the muscular and proper currents, but also of that current which excites the inducing contraction.

If the insulating stratum exceeds certain limits of thickness, and the mixture has not a convenient degree of fluidity, the induced contraction is wanting. It is however impossible to determine within what limits of thickness in the stratum and fluidity in the mixture this occurs; it is sufficient for me to have established by experiment that in some cases the induced contractions are obtained, while there is interposed between the nerve and the muscle an insulating stratum which certainly arrests the muscular and proper current, no less than an ordinary voltaic current.

I shall say, finally, that I have never succeeded in obtaining the induced contraction when using a solid body interposed, however thin it might have been chosen, and whatever might be its nature. For this purpose I used flakes of mica extremely thin, flakes of sulphate of lime, gold leaf, paper smeared with glue, and leaves of vegetables. The induced contraction is always wanting. It is however a very curious, and I believe even important fact in its consequences, to obtain the induced contraction through the skin of the muscles of the inducing frog. The experiment never fails of success, whether the inducing contraction be excited by the electric current, or by any stimulus applied to the lumbar plexuses of the inducing frog.

Having thus described a long series of facts relative to the circumstances that intervene in producing, in modifying, and in destroying the phenomenon of induced contraction, it might be believed that with the aid of these I might ascend to the physical theory of the phenomenon.

Unfortunately I am rather doubtful of it, and in this uncertainty I again beg the reader to follow me in the discussions that I shall be compelled to make upon the different hypotheses that may be imagined by which to interpret the phenomenon of induced contraction.

I. It is sufficient to have once seen the induced contraction originated by arousing the inducing contraction by any mechanical stimulus, to no longer have any kind of suspicion that the electric current used for exciting the contraction is propagated to the nerve of the galvanoscopic frog*. How must we understand the induced contraction of the second and third order? How are we to explain the fact that the induced contraction is wanting (although the current may be applied as usual upon the lumbar plexuses of the inducing frog), only because by the section of the nerves in the thigh the inducing contraction is prevented, or at least greatly weakened? Why is the induced contraction wanting when we apply the same current upon the nerves below the thigh in which there are no inducing contractions? Why, when we act with a current upon the lumbar plexuses of a frog already weakened so as no longer to have the contractions except at the beginning of the direct current or the cessation of the inverse, why in these cases alone is there induced contraction?

It is useless to continue to enumerate the objections that may be made to the interpretation of induced contraction by referring to the diffusion of the current exciting the inducing contractions, a diffusion that can in no way be physically conceived.

II. It might be suspected that the induced contraction was the result of a mechanical stimulus—of the shock of the inducing muscles, which, in their contraction, shake the nerve of the galvanoscopic frog. I have attempted many times (using extremely delicate galvanoscopic frogs) to produce motion in the muscular masses of the thighs in every possible way, and I never could see the galvanoscopic frog contract itself. If the occasion of the phenomenon were this shock, how could we explain the cessation of the induced contraction by the interposition of a very thin sheet of gold leaf or mica between the nerve and the muscle?

I have very many times tried to apply the nerve of the galvanoscopic frog upon plates of metal and glass, upon stretched membranes, upon cords of catgut while they were vibrating, and there was never any sign of contraction in the galvanoscopic frog. It is not then the shock of the muscle in contraction against the nerve of the galvanoscopic frog that occasions the induced contraction.

III. It happens very rarely that the contraction in the galvanoscopic frog is obtained when the nerve is being stretched over the thigh of the other frog, and this even when both are perfectly insulated. It is however certain that every time that this happens the occasion does not fail to be discovered. It either consists in the inside of the muscle being uncovered in some points, or because the nerve of the galvanoscopic frog remains united to some piece of muscle, that folding back again touches the nerve when this is extended over the thigh. It has also appeared to me that sometimes these contractions occur when the tendinous extremities and the surface of the muscle and of the thigh touch two points of the nerve of the galvanoscopic frog. So let us say that the induced contraction takes place constantly in all cases in which, by the care taken, the above-mentioned circumstances that may awake the contraction of the galvanoscopic frog are verified. We know too that having cut with scissors the muscular superficies of the thighs, and rendered them thus quite uniform, the induced contraction continues, when the nerve of the galvanoscopic frog is applied upon the new internal surface of the muscle. This induced contraction subsists even through the skin of the frog, and on interposing insulating liquid layers between the nerve and the muscle. We have seen that the insulating power of those layers was such as not to permit the circulation of the proper and muscular currents. How then can it be supposed that the induced contraction should take its origin from the above stated circumstances, even admitting that they may be rendered more active, or that they may be excited by the muscular contraction? These circumstances reduce themselves to the phenomenon of a muscular current or of a proper current, which ought to traverse the nerve of the galvanoscopic frog, while that nerve would be enveloped by a stratum of an insulating substance, which we have seen cannot be.

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* Through excess of caution I have many times endeavoured to obtain the induced contraction by exciting the inducing contraction from the laceration of the spinal marrow by means of a fragment of glass; the induced contraction has taken place as if the inducing contraction had been excited by the current, or by any other stimulus.

IV. The first idea conceived by which to interpret the induced contraction, was that of an evolution of electricity which might accompany the muscular contraction. There is evolution of heat in the act of contraction; and, according to the important observation of Quatrefage, which there is much necessity for repeating, in order to exactly establish its details, there would appear to be development of light in certain cases of muscular contraction; so that analogy might lead us to infer the probability of the production of electricity by the muscular current: besides, the few experiments that I made when I discovered the induced contraction might very well be interpreted on this hypothesis. An insulating body, as a lamina of mica or varnished paper, when interposed, impeded the induced contraction: and it could not be otherwise. The same thing occurred even when a lamina of gold perfectly discharging the electricity, that it is supposed is produced by the contraction, prevented the nerve from being traversed by it.

In spite of these first steps, which were flattering me into giving a very simple explanation of the induced contraction and were leading me at the same time to prove an important phenomenon in the muscular contraction, I am now constrained to entirely abandon this idea because it is contradicted by experiment.

In the beginning of this memoir, I referred at all possible length to the many experiments made by which to examine if there is any augmentation of the muscular current, or of the proper one in the act of contraction. All my efforts have been useless, and I have been obliged to conclude that experience does not prove that the signs of the muscular or proper currents increase in the act of muscular contraction.

We might believe it to be owing to an evolution of electricity independent of the muscular and proper current; but how can we suppose it so, when we see that the induced contraction propagates itself through certain insulating strata, as turpentine, oil, &c., while it does not take place if we use an extremely thin plate of mica? It might be supposed that the electricity developed in the muscular contraction could have acted by induction. In this hypothesis it is clear why the turpentine does not stop the induced contraction, but it still remains doubly obscure why with the extremely thin plate of mica this should take place. I have made an experiment by covering a galvanoscopic frog, placed upon a plate of glass, with a sheet of mica; the electric discharge of a jar passes between the knobs of the universal discharger upon the sheet of mica, and the contractions in the galvanoscopic frog are aroused. I shall not occupy myself at this moment in analysing these facts; it is sufficient at present to prove that there must be induced contractions through the plate of mica if the occasion of the phenomenon were an electric discharge. I will add finally, that I have very many times attempted, and always uselessly, to awaken the contractions in the frog, by holding the nerve of the galvanoscopic frog near and almost in contact with a metallic conductor traversed by the electric current.

To place myself in favourable circumstances that the induced current may be complete in the frog, I prepare it in such a manner that a long nervous filament (that is, one of the lumbar plexuses with its continuation in the thigh) may be uncovered. The frog is otherwise intact, and the two legs touch each other. I support the frog with silken threads, so that it may be horizontal, and that its nervous filament may be in contact and parallel with the voltaic conductor which is varnished. When every care is taken to insulate the frog, signs of contractions are never seen in it either at the closing or the opening of the circle of the pile. It is seen that by this disposition the induced circuit may take place in the frog. I have used a Bunsen's pile of ten elements without any result.

There is therefore given no experimental proof of that explanation of the phenomenon of induced contraction which admits an evolution of electricity in the act of muscular contraction.

We are still ignorant of the cause of muscular contraction, and we know nothing of this phenomenon except that it occurs on acting even at a great distance from the muscle upon the nerve that ramifies within it; that this action requires for its propagation the integrity of the nervous filament from the point at which it is acted upon to the muscle; that this propagation acts with a velocity which we cannot judge to be less than that of light and heat and electricity in their different media; that that which modifies, augments, or destroys the complication of the physico-chemical phenomena comprehended in the nutrition of the muscles, operates equally upon its contractility under any stimulus affecting the nerves; finally, that the phenomenon of the contraction of a muscle ought to be understood, with the condition that whatever be the cause of this phenomenon, it acts in accordance with the physical law of elastic bodies. The phenomenon of induced contraction would seem to be a first fact of induction of that force which circulates in the nerves and which arouses muscular contraction.

Admitting that we cannot give a satisfactory explanation of the phenomenon of induced contraction by recurring to electricity or any other known causes, as I think I have abundantly proved, it appears to me that we cannot, confining ourselves to a first fact, as is that of induced contraction, interpret it differently from what we have done. The induced contraction is only a new phenomenon of nervous force, a phenomenon of which we have given the principal laws in this memoir. It seems to me therefore more just to call that henceforth *muscular induction*, which I have hitherto called induced contraction. I shall conclude this memoir with some applications of muscular induction to physiology.

By the experiment described above (fig. 14.), it is proved that the muscular induction is propagated in a nerve at the same time towards the two extremities—towards the muscle as well as towards the nervous centre. If the muscular induction not only acts upon the nerve in contact with the muscle but also through some interposed bodies, it is natural to admit that when a muscular mass enters into contraction by the irritation acting on one of its nerves, the phenomenon of induction should occur in all the other nerves. And even wishing to yield for a moment to the analogies that exist between the electric current and the nervous force, we might be led to believe that this induction should take place upon the excited nerve which is the cause of the contraction. Could we not perhaps from this deduce a physical explanation of a well-established physiological fact, that within certain limits the activity of the muscles increases in proportion as the contraction is aroused in them?

It also appears to me that a great number of those movements which occur in us and in animals independently of the will, but yet following others occasioned by the will, may be considered as phenomena of muscular induction. I leave to physiologists the continuation of these studies, which appear to me worthy of all their interest.

I shall terminate by citing an experiment which I think proves an action of this nature. Having prepared a frog in the ordinary manner, I cut one of the nerves that constitute one of the lumbar plexuses, and I divide it precisely at the point of exit from the vertebral column. Having extended the frog upon turpentine, I draw on one side the severed nerve, and I irritate it either with the current or with an alkali. Thus very strong contractions are produced in the thigh, and at the same time, if the frog is very lively, there are contortions in the back and movements in its superior limbs.

# XIV. *On the Temperature of Man.*

*By* JOHN DAVY, *M.D., F.R.S.L. & E., Inspector-General of Army Hospitals.*

Received May 8,—Read June 19, 1845.

IT has been too generally taken for granted that the temperature of man in health, as measured by a thermometer placed under the tongue, is a constant one. I have endeavoured to prove from the results of observations, that this is not strictly correct; that when not disturbed by disease it is subject to variation, to rise and fall under certain influences, especially of heat and cold, rest and exercise*.

In the present communication I propose to submit to the Royal Society some further observations on the same subject, made with an instrument better adapted for the inquiry than the medical thermometer commonly used, and which has afforded results of a precise and satisfactory kind.

The thermometer I have employed is a bent one, about twelve inches and a half long, its bulb about an inch long, and, where widest, half an inch thick; its curvature about three and a half inches from the bulb, and its stem, to which the scale is attached, nearly at right angles to the bulb, so that when inserted under the tongue, the observer has no difficulty in distinguishing accurately the degrees himself, whether near-sighted or the contrary; in the latter instance using merely a common magnifying glass. Each degree of the scale is a little more than half an inch (·6 inch), and is divided into ten parts; and each of these parts is sufficiently large to admit of subdivision by the eye.

It may be right to premise a few words regarding the manner of observing with this instrument; and to notice some precautions which it is necessary to take to avoid error.

First, as to the placing of the thermometer: it is requisite that the bulb should be introduced under the tongue, and as far back as possible; and that whilst in the mouth, respiration should be carried on entirely through the nostrils. If the thermometer is placed in the side of the mouth, between the teeth and the cheek, the temperature indicated is from three-tenths to one-tenth of a degree less, according to the degree of coldness of the atmosphere.

Next, as to time: it is necessary that the thermometer remain in the mouth many minutes, till the observer is sure that the maximum height is attained. If the mouth has been kept closed for a quarter of an hour previously, a shorter time is required, than if allowed to be open and the passage of respiration. This is well shown by trials with the thermometer raised a few degrees above the temperature of the mouth before introduction. In the one case, the thermometer slowly falls to the temperature of the mouth, and is stationary; in the other case, after having fallen it again rises, continuing to rise till the maximum temperature of the closed mouth is acquired.

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* Researches, Physiological and Anatomical, vol. i. p. 162; and Philosophical Transactions for 1844, p. 61.

The observations which I have made with this thermometer have been altogether on myself; it would have been difficult indeed to have made them on another, with the requisite degree of accuracy, as they are tedious, demanding so much time and care. They were begun in August last, and have been continued almost daily up to the present time, with the exception of the greater part of the month of October, when they were interrupted until a second thermometer could be procured to supply the place of the first, which was then broken, and which was even more delicate than the second. It was my intention to have extended them to a period of twelve months before collecting the results; but this I am not able to accomplish, having received an order to prepare and hold myself in readiness for foreign service. Abroad I hope to be able to continue them, and as that will be in a tropical climate, I am the more desirous of communicating now the information I have already obtained; the comparison of the two sets may prove interesting.

In conjunction with the temperature under the tongue, I have in most instances noticed the pulse and respiration, considering it a desideratum so to do, and with the hope that the observations on the latter may be useful data, and may in some measure tend to throw light on the former, there being such an intimate connexion between them. The posture in which the pulse and respiration have been counted has always been a sitting one.

Of the many problems which might be proposed regarding the temperature of the body, I shall now only touch on a small number; and I shall be well-pleased if the information I have to give shall be considered merely as a contribution towards their solution, a beginning of an inquiry to be extended.

### 1. *Of the Variation of Temperature during the twenty-four hours.*

To endeavour to determine what is the extent of this variation, I have made on several occasions, observations every second or third hour, from the time of rising to that of going to rest, confining myself to the house during the whole time and to rooms of nearly the same temperature, the greater part of it, and varying but little my occupation. The following for a single day will give a pretty accurate idea of the result:—

| | Temperature under tongue. | Pulse. | Respirations. | Temperature of air of room. | |
|---|---|---|---|---|---|
| April 13. 7 A.M. | 98°·5 | 54 | 15 | 49° | Just after rising. |
| 9 A.M. | 98·4 | 74 | 16 | 53 | Just after breakfast. |
| 11 A.M. | 98·4 | 60 | 15 | 53 | |
| 2 P.M. | 98·7 | 54 | 15 | 55 | |
| 4 P.M. | 98·9 | 54 | 15 | 55 | |
| 5 P.M. | 98·7 | 54 | 15 | 55 | |
| 6½ P.M. | 98·3 | 62 | 16 | 57 | Shortly after dinner. |
| 7½ P.M. | 97·7 | 66 | 15 | 56 | Before drinking tea. |
| 11 P.M. | 98·1 | 52 | 15 | 64 | |
| 14. 1 A.M. | 97·6 | 54 | 15 | 60 | |

During the whole period, I have almost constantly tried the temperature under the tongue on rising and before going to rest, and in many instances in the middle of the day, between 2 and 4 P.M., when the circumstances were favourable. These observations I shall give in detail in tables appended; here it may be sufficient to notice the mean of each month's observations.

| | Temperature under tongue. | | | Pulse. | | | Respirations. | | | Temperature of air of room. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| August .... | 98°·7 | 98°·5 | 98°·0 | 56·9 | 52·5 | 53·1 | 15·3 | 15·1 | 15 | 61° | 63° | 67° |
| September .. | 98·8 | 98·9 | 98·0 | 59·3 | 55·2 | 55·8 | 15·5 | 15 | 15·4 | 66 | 63 | 65 |
| November .. | 98·9 | 98·6 | 97·9 | 57·8 | 57·6 | 54·5 | 16·7 | 17·1 | 15·8 | 51 | 48 | 64 |
| December .. | 98·7 | 98·2 | 97·9 | 58·9 | 55·2 | 56·5 | 15·7 | 16 | 15·4 | 42 | 47 | 60 |
| January .... | 98·8 | 98·07 | 97·9 | 58·7 | 59·3 | 57·9 | 15·5 | 15·3 | 15·1 | 45 | 55 | 60 |
| February .. | 98·6 | 98·6 | 97·9 | 55·5 | 54·4 | 52·3 | 15·5 | 15 | 15·1 | 42 | 48 | 61 |
| March .... | 98·74 | 98·59 | 97·93 | 57 | 53 | 54 | 15·1 | 15·1 | 15 | 46 | 54 | 60 |
| April ...... | 98·66 | 98·57 | 97·88 | 56·5 | 54·8 | 53·6 | 15·4 | 15 | 14·8 | 54·6 | 59·8 | 62·4 |
| | 98·74 | 98·52 | 97·92 | 57·6 | 55·2 | 54·7 | 15·6 | 15·4 | 15·2 | 50·9 | 54·7 | 62 |

During this period, comprising eight months, the health of the observer (aged fifty-five) was pretty good, almost uninterruptedly so, excepting in December and January, when he experienced slight lumbago, not preventing the taking of exercise; and for a few days in November and January an attack of catarrh in a mild form.

As I wish to be as concise as possible, I shall comment very little on the results of the summary of observations. They seem to prove in a decided manner that the temperature under the tongue, when under no disturbing influence, is about its maximum after waking after the repose of the night; that it continues high, but fluctuating more or less (probably owing to disturbing circumstances) till towards nightfall; and that it is lowest about midnight. Its lowness at the last-mentioned time is the more remarkable, as the temperature of the room in which the observer sat at night was almost uniformly higher than of that which he occupied during the day.

### 2. *Of the Variation of Temperature during different seasons of the year.*

The following Table exhibits the mean results of the observations made during the eight months, at the different periods of the day, both of the temperature under the tongue and of the air of the room.

| | Mean temperature under the tongue. | Air of room. |
|---|---|---|
| August .... | 98°·4 | 63°·7 |
| September .. | 98·57 | 64·7 |
| November .. | 98·47 | 54·3 |
| December .. | 98·27 | 49·7 |
| January .... | 98·36 | 53·3 |
| February .. | 98·37 | 50·3 |
| March .... | 98·42 | 53·3 |
| April ...... | 98·37 | 55·5 |

These results give an average temperature of 98·4, that of the air being about 55·5. They show a slight relation between the temperature of the body and of the air, but less perhaps than might be expected, and less unquestionably than would have been exhibited under circumstances not equally favourable for the preservation of an equable warmth, especially at night, in the uniform temperature of the sitting-room; and when at rest, from warm bed-clothes, and during the day from sitting in cold weather near a fire, and from the clothing then, as well as at night, being varied with the degree of cold to be resisted, having in view the preserving of an agreeable feeling. The effect and perhaps best sign of the happy temperate mean in some facts which I shall have presently to bring forward, may aid in illustrating the remark just made.

### 3. *Of the Effect of Active Exercise on the Temperature.*

By active exercise, I mean that which occasions acceleration of the heart's action, and of respiration, and commonly a feeling of increased warmth, such as fast walking and riding, in contradistinction to the passive kind, as that which is taken in an easy carriage.

The following detail exhibits the results of observations made immediately after active exercise, in different months and under various circumstances:—

| | Tongue. | Pulse. | Respirations. | Air. |
|---|---|---|---|---|
| August 15, 5 P.M. After fly-fishing by the river side, and riding about seven hours; feet and hands warm | 99°·4 | 80 | 18 | 63° |
| August 17, 3 P.M. After a walk of three miles; gently perspiring | 99·0 | 70 | 16 | 56 |
| August 20, 5 P.M. After fishing five hours; gently perspiring | 99·3 | 80 | 20 | 62 |
| August 27, 2 P.M. After a ride (pretty fast) of five miles; feet and hands warm | 98·7 | 58 | 16 | 64 |
| August 29, 5 P.M. After a ride (pretty fast) of about fourteen miles; sun powerful; perspiring | 99·5 | 84 | 18 | 64 |
| August 31, 12 M. After a ride of ten miles; perspiring | 99·1 | 60 | 16 | 65 |
| August 31, 4 P.M. After an hour's walk; sun powerful; perspiring | 99·3 | 64 | 18 | 70 |
| September 2, 12 M. After a walk of two hours; the sun powerful; perspiring | 99·2 | 64 | 18 | 72 |
| October 30, 5 P.M. After a ride of ten miles (pretty fast); feet and hands warm | 99·3 | 78 | 16 | 49 |
| November 16, 4 P.M. After fishing two hours; slightly perspiring | 98·9 | 62 | 18 | 55 |
| December 31, 3 P.M. After riding and walking several hours; feet and hands warm | 99·1 | 74 | 16 | 34 |
| February 3. After a walk of seventeen miles; moderately warm | 99·1 | 98 | 22 | 32 |
| March 7, 5 P.M. After a mountain excursion on foot for several hours, and riding ten miles | 99·2 | 90 | 17 | 33 |
| March 20, 3 P.M. After a ride of ten miles; feet and hands warm | 98·9 | 56 | 16 | 37 |
| March 31, 1 P.M. After two hours' fishing; pleasantly warm | 98·9 | 62 | 16 | 54 |
| April 2, 1 P.M. After riding ten miles; moderately warm | 98·9 | 62 | 16 | 54 |
| April 11, 4 P.M. After five hours' fishing; not heated | 99·0 | 70 | 16 | 40 |
| April 17, 2 P.M. After four hours' fishing; slightly perspiring | 99·2 | 84 | 18 | 55 |

These observations, selected from a large number of similar bearing, show in a decided manner, that active exercise, not carried to the extent of exhausting fatigue, raises the temperature of the body; and that the increase is, at least within a certain limit, proportional to the degree of muscular exertion made.

### 4. *Of the Effect of Carriage Exercise on the Temperature.*

The observations which follow, were made immediately after getting out of the carriage, which was a close one, and its windows commonly closed; and the dress worn, at the time of being out, was warm.

| | | Tongue. | Pulse. | Respiration. | Air. |
|---|---|---|---|---|---|
| Nov. 17. 1 P.M. | After a drive of 8 miles. | 97°·7 | 52 | 18 | 53° |
| 19. 3 P.M. | After a drive of 10 miles. | 97·7 | 48 | 16 | 48 |
| 25. 2 P.M. | After a drive of 10 miles. | 97·0 | 56 | 16 | 44 |
| 27. 12 M. | After a drive of 8 miles. | 97·5 | 56 | 18 | 42 |
| 30. 12 M. | After a drive of 8 miles. | 97·4 | 56 | 16 | 44 |
| Jan. 5. 5 P.M. | After a drive of 7 miles. | 97·7 | 50 | 17 | 32 |

Feet and hands cool, almost cold, as was experienced in all the preceding instances.

These results are strongly contrasted with those given in the preceding section, showing the exalting effect of active exercise on the temperature. I have other results, equally proving how gentle exercise, in a cold atmosphere, has a depressing effect, whether taken in a carriage, on horseback, or on foot, walking slowly.

### 5. *Of the Effect of Exposure to Cold Air without exercise.*

The few observations I have collected on this point, have been made the instant after returning from an adjoining church, the temperature of which in the cold weather of winter is little above the freezing-point, no attempt being made to warm it, and the congregation which assembles in it at that season being small.

| | Tongue. | Pulse. | Respirations. | Air. |
|---|---|---|---|---|
| Nov. 24. 1 P.M. | 97°·0 | 52 | 16 | 42° |
| Jan. 12. 1 P.M. | 97·1 | 50 | 15 | 40 |
| Feb. 9. 1 P.M. | 96·7 | 48 | 15 | 33 |
| March 16. 1 P.M. | 95·9 | 44 | 16 | 32 |

In each of the above instances, in spite of warm clothing, the sensation experienced by the observer was that of disagreeable chilliness, and in the feet and hands, of coldness; a feeling of drowsiness was also perceived, as if the condition induced were an approach to the state of temperature of a hybernating animal, or to that which is probably the prelude to the sleep in the human being resulting from long exposure to severe cold without exercise.

### 6. *Of the Effect of Excited and Sustained Attention on the Temperature.*

The state of mind referred to is that accompanied with exertion, such as is experienced in composition, or in reading a work of exciting interest.

The observations which follow have been made entirely at night, after from two to five hours of sustained attention. Many more were made by day; but these are not given, as they are not so well fitted for comparison.

| | Tongue. | Pulse. | Respirations. | Air. |
|---|---|---|---|---|
| Aug. 19. 12 P.M. | 98·45° | 58 | 15 | 68° |
| 29. 11 P.M. | 98·5 | 62 | 16 | 62 |
| Sept. 23. 1 A.M. | 98·5 | 54 | 16 | 65 |
| Nov. 26. 12 P.M. | 98·4 | 56 | 15 | 60 |
| 28. 12 P.M. | 98·7 | 60 | 16 | 62 |
| Dec. 14. 1 A.M. | 98·5 | 56 | 15 | 64 |
| 20. 1 A.M. | 98·7 | 58 | 16 | 60 |
| 30. 1 A.M. | 98·0 | 56 | 16 | 55 |
| Jan. 23. 12 P.M. | 98·35 | 60 | 14 | 61 |
| Feb. 3. 1 A.M. | 98·4 | 60 | 17 | 60 |
| 12. 12 P.M. | 98·2 | 58 | 16 | 60 |
| 21. 1 A.M. | 98·4 | 54 | 15 | 60 |
| 24. 2 A.M. | 98·4 | 58 | 14 | 60 |
| 26. 2 A.M. | 98·0 | 56 | 15 | 60 |
| Mar. 4. 1 A.M. | 98·5 | 56 | 15 | 60 |
| 11. 12 P.M. | 98·5 | 52 | 14 | 60 |
| 14. 1 A.M. | 98·2 | 54 | 15 | 61 |
| April 3. 12 P.M. | 98·4 | 58 | 16 | 68 |
| | 98·4 | | | |

These observations show an increase of temperature after sustained exertion of mind. Though the increase is slight, yet I think it must be admitted to be decided, comparing the mean (98·4) with the average result of the observations (97·92) made at the same period of the twenty-four hours, when the attention was not roused, when it was rather in a passive indolent state, as in reading merely for amusement, or in the mechanical process of copying writing, both which seem to have, as is indeed generally believed, rather a sedative influence than an exciting one; and are to the former very like what passive bodily exercise is to active muscular exertion.

### 7. *Of the Effect of taking Food on the Temperature.*

The following observations were made after rising from the dinner-table, at which the observer commonly sat down at 5 o'clock, and partook pretty fully, using a mixed diet,—never taking anything between the breakfast and dinner-hour,—and using wine commonly at the latter meal, to the extent of three or four glasses, to the exclusion of malt liquor.

| | Tongue. | Pulse. | Respirations. | Air. |
|---|---|---|---|---|
| Aug. 15. 7 P.M. | 98·2° | | | ° |
| 22. 6½ P.M. | 97·9 | 60 | 16 | 60 |
| 25. 6½ P.M. | 98·1 | 62 | 15 | 59 |
| 27. 6½ P.M. | 98·4 | 58 | 16 | 62 |
| 28. 7 P.M. | 98·6 | 76 | 16 | 68 |
| 29. 7 P.M. | 98·3 | 82 | 16 | 63 |
| Sept. 2. 6 P.M. | 98·5 | 68 | 18 | 17 |
| 3. 6 P.M. | 98·3 | 60 | 15 | 70 |
| 8. 8 P.M. | 97·8 | 60 | 15 | 65 |
| 22. 6½ P.M. | 98·4 | 70 | 15 | 55 |
| 29. 6 P.M. | 98·5 | 68 | 16 | 62 |
| Nov. 16. 7 P.M. | 97·9 | 62 | 15 | 60 |
| 23. 7½ P.M. | 98·1 | 70 | 18 | 54 |
| Dec. 21. 7 P.M. | 97·9 | 70 | 14 | 63 |
| 28. 7 P.M. | 97·7 | 64 | 15 | 58 |
| 29. 8 P.M. | 98·0 | 70 | 15 | 55 |
| Jan. 2. 6½ P.M. | 97·9 | 68 | 15 | 55 |
| Mar. 24. 6½ P.M. | 98·5 | 66 | 15 | 52 |
| | 98·1 | | | |

The majority of these results (the mean temperature of the whole being 98·1) seem to prove, that the amount of heat is reduced by a full meal. In the observer's case, as in most others, drowsiness followed this meal, thus approximating the condition of the animal system to that which precedes sleep. On particular occasions, when a larger quantity of wine than usual was taken, the reduction of temperature was commonly most strongly marked. A light meal, such as that of breakfast, consisting of tea, with a portion of toasted bread with butter, and often an egg, has had little effect in depressing or altering materially the temperature. It may be noticed, as regards the habits of the observer, in connexion with the observations on temperature made at a late hour, that after dinner he never took solid food, only two or three cups of tea, and this about 8 P.M.

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The preceding observations, generally considered, appear to indicate clearly that the temperature of man, as determined in the manner described, is like the animal functions and secretions, constantly fluctuating within certain limits; and like them, observing in its fluctuation a certain order, constituting as it were two series; one regular, as the diurnal, connected with rest and refreshment from rest; the other, casual or accidental, depending on varying circumstances of irregular occurrence, as exercise, mental exertion, exposure to heat, and the contrary.

As the observations brought forward have been made on one individual, the inferences from them as regards extended application, can be held to be only probable, but probable, I cannot but think, in a high degree, the average temperature of the observer being nowise peculiar; and the results moreover being what might be expected reasoning on the subject, taking for data the proportions of oxygen which have been ascertained to be consumed, and of carbonic acid evolved in respiration, at different periods of the twenty-four hours, and under different circumstances.

Should observations similarly made on others present the like results (and I cannot but be confident that they will), more particular inferences may be drawn from them, especially in conjunction with respiration and the heart's action, not without interest to physiology; and they may admit of important practical application to the regulation of clothing, the taking of exercise, the warming of dwelling-rooms, in brief, to various measures conducive to comfort, the prevention of disease, and its cure. A step in advance is made, if it is only determined, as I believe it to be, that in the healthiest condition of the system, there is danger attending either extreme, either of low uniform temperature, or of a high uniform temperature, and that the circumstances which are proper to regulate variability within certain limits, not prevent it, are those which conduce most to health, as well as to agreeable sensation, enjoyment and length of life.

*The Oaks, Ambleside,*
*May* 1, 1845.

## APPENDIX.

The Tables which follow, containing the monthly observations, require little additional explanation. It may be right to state, that they do not include the observations made under the influence of accidental disturbing circumstances, as active exercise, &c., the most distinct of which have been given apart in a section appropriated to them. The observations in these Tables, made under ordinary circumstances, or nearly such, will, I believe, be useful for comparison with the former, and I would hope, for reference, in progress of inquiry. In most instances, it will be found on comparison, that an unusual elevation of temperature has been followed by unwonted depression, and *vice versâ*.

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Aug. 6. | 98°·3 | °.... | 97°·9 | | | | | | | ° | ° | ° |
| 7. | 98·8 | .... | 98·2 | 56 | .... | 54 | 13 | .... | 15 | 63 | .... | 68 |
| 8. | 98·6 | 98·5 | 97·8 | 56 | 52 | 52 | 13 | 14 | 16 | 63 | 60 | 66 |
| 9. | 98·8 | .... | 98·2 | 60 | .... | 62 | 14 | .... | 16 | 63 | .... | 70 |
| 10. | 98·8 | .... | 97·8 | .... | .... | 70 | .... | .... | 14 | .... | .... | 70 |
| 11. | 98·5 | 98·6 | 98·0 | 56 | 50 | 58 | 14 | 15 | 16 | 62 | 59 | 67 |
| 12. | 98·6 | .... | 98·0 | .... | .... | 58 | .... | .... | 14 | .... | .... | 68 |
| 13. | 98·7 | 98·5 | 97·7 | 52 | 52 | 58 | 14 | 15 | 16 | 61 | 62 | 68 |
| 14. | 98·8 | 98·7 | 98·1 | 56 | 60 | 52 | 15 | 16 | 15 | 62 | 64 | 61 |
| 15. | 98·7 | .... | .... | 58 | .... | .... | 16 | .... | .... | 64 | | |
| 16. | 98·5 | 98·5 | 97·6 | 56 | 50 | 50 | 16 | 14 | 15 | 63 | 63 | 63 |
| 17. | 98·8 | 98·5 | 98·1 | 54 | 50 | 50 | 15 | 15 | 14 | 62 | 62 | 68 |
| 18. | 98·7 | 98·4 | 98·2 | 62 | 54 | 56 | 16 | 15 | 16 | 60 | 68 | 68 |
| 19. | 98·8 | 98·4 | 98·4 | 66 | 50 | 58 | 18 | 14 | 15 | 60 | 63 | 68 |
| 20. | 98·7 | .... | 97·9 | 54 | .... | 58 | 16 | .... | 15 | 62 | .... | 68 |
| 21. | 98·6 | .... | 98·0 | 58 | .. . | 56 | 16 | .... | 15 | 62 | .... | 66 |
| 22. | 99·0 | .... | 98·0 | 56 | .... | 58 | 16 | .... | 15 | 60 | .... | 68 |
| 23. | 98·6 | .... | 97·7 | 52 | .... | 52 | 16 | .... | 16 | 60 | .... | 68 |
| 24. | 98·5 | 98·5 | 97·8 | 52 | 50 | 48 | 16 | 16 | 14 | 60 | 61 | 68 |
| 25. | 98·7 | 98·8 | 98·4 | 56 | 54 | 60 | 15 | 15 | 16 | 60 | 54 | 66 |
| 26. | 99·0 | .... | 98·1 | 58 | .... | 50 | 15 | .... | 15 | 60 | .... | 65 |
| 27. | 98·7 | .... | 98·2 | 54 | .... | 52 | 15 | .... | 15 | 60 | .... | 62 |
| 28. | 98·7 | 98·8 | 98·1 | 60 | 54 | 54 | 15 | 17 | 17 | 62 | 72 | 68 |
| 29. | 98·8 | .... | 98·5 | 54 | .... | 62 | 16 | .... | 16 | 61 | .... | 62 |
| 30. | 98·9 | 98·8 | 97·7 | 62 | 54 | 50 | 16 | 15 | 16 | 60 | 63 | 63 |
| 31. | 98·7 | .... | 97·8 | 62 | .... | 58 | 16 | .... | 16 | 65 | .... | 68 |
| | 98·7 | 98·5 | 98·0 | 56·9 | 52·5 | 53·1 | 15·3 | 15·1 | 15 | 61 | 63 | 67 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Sept. 1. | 98°·7 | 98°·7 | 97°·8 | 62 | 56 | 56 | 17 | 16 | 15 | 67° | 67° | 67° |
| 2. | 98·8 | 98·7 | 98·1 | 54 | 54 | 54 | 16 | 16 | 16 | 68 | 71 | 68 |
| 3. | 98·9 | 98·7 | 98·3 | 58 | 54 | 54 | 16 | 15 | 16 | 70 | 71 | 68 |
| 4. | 99·0 | .... | 98·1 | 60 | .... | 48 | 16 | .... | 14 | 72 | .... | 70 |
| 5. | 98·8 | 98·6 | 98·1 | 62 | 54 | 60 | 16 | 16 | 15 | 70 | 68 | 68 |
| 6. | 98·8 | .... | .... | 60 | .... | .... | 15 | ... | .... | 69 | .... | .... |
| 7. | 98·7 | 98·7 | 98·2 | 60 | 60 | 56 | 15 | 16 | 16 | 68 | 68 | 68 |
| 8. | 98·8 | 98·9 | 97·8 | 54 | 60 | 52 | 15 | 15 | 16 | 62 | 65 | 64 |
| 9. | 99·0 | 99·0 | 98·1 | 58 | .... | 50 | 15 | .... | 15 | 64 | .... | 64 |
| 10. | 99·0 | .... | .... | 60 | .... | .... | 15 | .... | .... | 64 | .... | .... |
| 11. | .... | .... | 97·6 | .... | .... | 50 | .... | .... | .... | .... | .... | 67 |
| 12. | 98·7 | .... | 98·2 | 56 | .... | 50 | 15 | .... | 15 | 62 | .... | 64 |
| 13. | 98·8 | 98·8 | 98·1 | 66 | 52 | 54 | 16 | 17 | 16 | 62 | 60 | 68 |
| 14. | 99·0 | 98·7 | 98·0 | 62 | 52 | 50 | 16 | 16 | 15 | 61 | 60 | 60 |
| 15. | 99·0 | 99·0 | 98·2 | 66 | 58 | 54 | 16 | 18 | 17 | 63 | 60 | 69 |
| 16. | 98·8 | .... | 97·9 | 66 | .... | 52 | 16 | .... | 15 | 62 | .... | 68 |
| 17. | 98·6 | .... | 97·7 | 64 | .... | 64 | 15 | .... | 16 | 62 | .... | 68 |
| 18. | 99·0 | .... | 98·4 | 62 | .... | 50 | 17 | .... | 14 | 62 | .... | 61 |
| 19. | 99·0 | 99·0 | 97·9 | 64 | 60 | 54 | 15 | 16 | 16 | 60 | 62 | 63 |
| 20. | 99·0 | .... | 98·3 | 58 | .... | 52 | 15 | .... | 16 | 60 | .... | 58 |
| 21. | 99·0 | .... | 98·1 | 60 | .... | 54 | 16 | .... | 15 | 58 | .... | 58 |
| 22. | 99·0 | 99·0 | 98·5 | 54 | 48 | 54 | 15 | 16 | 16 | 58 | 55 | 65 |
| 23. | 99·0 | .... | 97·7 | 56 | .... | 52 | 16 | .... | 14 | 65 | .... | 68 |
| 24. | 98·7 | .... | 98·3 | 54 | .... | 56 | 14 | .... | 15 | 58 | .... | 63 |
| 25. | 99·2 | .... | 97·2 | 58 | .... | 48 | 16 | .... | 16 | 63 | .... | 66 |
| 26. | 98·3 | 99·0 | 98·3 | 58 | 56 | 54 | 16 | 16 | 16 | 58 | 58 | 67 |
| 27. | 98·9 | .... | 98·0 | 58 | .... | 50 | 16 | .... | 15 | 60 | .... | 68 |
| 28. | 98·6 | .... | 97·7 | 60 | .... | 62 | 16 | .... | 14 | 62 | .... | 69 |
| 29. | 98·6 | 98·9 | 98·3 | 54 | 56 | 52 | 15 | 16 | 16 | 59 | 63 | 68 |
| 30. | 99·0 | .... | .... | 56 | .... | .... | 16 | .... | .... | 58 | .... | |
| | 98·8 | 98·9 | 98·0 | 59·3 | 55·2 | 55·8 | 15·5 | 16 | 15·4 | 66 | 63 | 65 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Nov. 1. | 98°·75 | 98°·8 | 97°·6 | 54 | 58 | .... | 16 | 17 | 16 | 53° | 54° | 62° |
| 2. | 98·8 | 98·5 | 97·7 | 60 | 58 | 54 | 17 | 18 | 16 | 52 | 44 | 60 |
| 3. | 98·6 | 98·5 | 97·9 | 52 | 48 | 48 | 16 | 17 | 17 | 50 | 55 | 65 |
| 4. | 98·7 | .... | 97·9 | 60 | .... | 70 | 16 | .... | 16 | 51 | .... | 66 |
| 5. | 98·9 | .... | 97·6 | 64 | .... | 52 | 16 | .... | 16 | 52 | .... | 68 |
| 6. | 99·2 | .... | 98·0 | 66 | .... | 58 | 17 | .... | 16 | 50 | .... | 63 |
| 7. | 98·7 | 98·7 | 98·3 | 58 | 58 | 58 | 16 | 16 | 16 | 51 | 46 | 62 |
| 8. | 99·5 | .... | 97·8 | 63 | .... | 54 | 17 | .... | 17 | 52 | .... | 68 |
| 9. | 98·8 | .... | .... | 62 | .... | .... | 16 | .... | .... | 51 | .... | .... |
| 11. | 99·3 | 98·3 | 97·8 | 62 | 61 | 50 | 17 | 17 | 15 | 52 | 54 | 68 |
| 12. | 98·6 | 98·7 | 98·2 | 60 | 56 | 52 | 17 | 17 | 15 | 47 | 40 | 65 |
| 13. | 98·8 | 98·7 | 98·1 | 56 | 62 | 54 | 16 | 17 | 16 | 52 | 50 | 62 |
| 14. | 98·5 | .... | 98·0 | 58 | .... | 58 | 16 | .... | 16 | 51 | .... | 64 |
| 15. | 98·8 | 98·7 | 97·9 | 56 | 56 | 60 | 16 | 17 | 17 | 54 | 55 | 63 |
| 16. | 98·9 | 98·9 | 97·7 | 56 | 62 | 58 | 15 | 18 | 15 | 55 | 55 | 68 |
| 17. | 98·7 | .... | 97·5 | 52 | .... | 52 | 18 | .... | 15 | 53 | .... | 65 |
| 18. | 98·6 | .... | .... | 54 | .... | .... | 15 | .... | .... | 55 | .... | .... |
| 19. | 99·1 | .... | 98·2 | 60 | .... | 56 | 17 | .... | 16 | 55 | .... | 66 |
| 20. | 99·1 | .... | 98·1 | 56 | .... | 56 | 17 | .... | 15 | 55 | .... | 65 |
| 21. | 98·9 | .... | 98·0 | 60 | .... | 58 | 17 | .... | 15 | 55 | .... | 62 |
| 22. | 99·0 | .... | 98·0 | 60 | .... | 56 | 16 | .... | 14 | 55 | .... | 66 |
| 23. | 99·0 | .... | 98·2 | 60 | .... | 62 | 16 | .... | 16 | 53 | .... | 65 |
| 24. | 99·0 | .... | 98·2 | 58 | .... | 62 | 16 | .... | 16 | 52 | .... | 64 |
| 25. | 99·2 | .... | 98·1 | 56 | .... | 56 | 17 | .... | 16 | 48 | .... | 60 |
| 26. | 98·8 | .... | 98·4 | 54 | .... | 56 | 15 | .... | 15 | 44 | .... | 60 |
| 27. | 98·7 | .... | 97·4 | 60 | ... | 50 | 16 | .... | 16 | 43 | .... | 62 |
| 28. | 98·6 | .... | .... | 54 | .... | .... | 17 | .... | .... | 48 | .... | .... |
| 29. | 99·2 | .... | 98·2 | 54 | .... | 60 | 16 | ... | 17 | 49 | .... | 64 |
| 30. | 99·0 | .... | 97·4 | 54 | .... | 56 | 17 | .... | 16 | 46 | .... | 62 |
| | 98·9 | 98·6 | 97·9 | 57·8 | 57·6 | 54·3 | 16·7 | 17·1 | 15·8 | 51 | 48 | 64 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Dec. 1. | 98°·7 | 98°·6 | 98°·3 | 62 | 58 | 50 | 17 | 16 | 16 | 50° | 54° | 64° |
| 2. | 98·8 | .... | .... | 54 | .... | .... | 16 | .... | .... | 48 | .... | .... |
| 3. | .... | .... | 97·0 | .... | .... | 56 | .... | .... | 15 | .... | .... | 62 |
| 4. | 98·7 | 98·7 | 97·7 | 56 | 60 | 50 | 16 | 19 | 15 | 44 | 32 | 58 |
| 5. | 98·7 | .... | 98·2 | 58 | .... | 58 | 16 | .... | 15 | 40 | .... | 62 |
| 6. | 98·9 | 97·8 | 98·3 | 56 | 56 | 60 | 16 | 17 | 16 | 38 | 43 | 60 |
| 7. | 98·6 | 98·0 | 98·2 | 56 | 54 | 60 | 15 | 16 | 14 | 36 | 47 | 62 |
| 8. | 98·5 | 98·4 | 98·1 | 56 | 50 | 54 | 16 | 16 | 16 | 38 | 43 | 60 |
| 10. | 98·4 | 98·2 | 97·9 | 56 | 54 | 52 | 16 | 16 | 16 | 40 | 44 | 62 |
| 11. | 98·5 | .... | .... | 58 | .... | .... | 16 | .... | .... | 40 | .... | .... |
| 13. | 98·6 | .... | 98·5 | 58 | .... | 56 | 17 | .... | 15 | 38 | .... | 64 |
| 14. | 98·4 | .... | 97·9 | 60 | .... | 58 | 16 | .... | 16 | 40 | .... | 58 |
| 15. | 99·0 | 98·6 | 98·3 | 63 | 54 | 56 | 15 | 15 | 16 | 42 | 48 | 62 |
| 16. | 98·4 | 97·9 | 98·1 | 56 | 56 | 66 | 16 | 15 | 16 | 42 | 58 | 60 |
| 17. | 99·0 | 97·7 | 98·0 | 60 | 50 | 58 | 15 | 17 | 14 | 45 | 50 | 64 |
| 18. | 98·7 | .... | 98·2 | 60 | .... | 58 | 15 | .... | 16 | 45 | .... | 62 |
| 19. | 98·8 | .... | .... | 58 | .... | .... | 15 | .... | .... | 45 | .... | .... |
| 20. | 98·8 | 98·0 | 97·5 | 64 | 56 | 54 | 15 | 16 | 15 | 43 | 43 | 65 |
| 21. | 98·6 | .... | 98·2 | 58 | .... | 50 | 15 | .... | 15 | 43 | .... | 58 |
| 22. | 98·8 | 98·4 | 97·8 | 52 | 52 | 62 | 16 | 15 | 14 | 43 | 50 | 66 |
| 23. | 98·9 | .... | 97·9 | 60 | .... | 54 | 15 | .... | 16 | 43 | .... | 62 |
| 24. | 98·6 | .... | 98·2 | 60 | .... | 54 | 15 | .... | 15 | .... | .... | 65 |
| 25. | 99·2 | .... | .... | 60 | .... | .... | 15 | .... | .... | 43 | .... | .... |
| 26. | 98·8 | 98·4 | 98·3 | 58 | 64 | 52 | 16 | 17 | 15 | 41 | 34 | 50 |
| 27. | 98·5 | .... | 97·7 | 58 | .... | 66 | 16 | .... | 16 | 43 | .... | .... |
| 28. | 99·3 | 98·7 | 97·5 | 66 | 58 | 52 | 16 | 16 | 15 | 41 | 53 | 55 |
| 29. | 98·2 | 98·6 | 98·0 | 50 | 52 | 56 | 16 | 15 | 16 | 45 | 58 | 55 |
| 30. | 98·8 | 98·9 | 97·3 | 60 | 62 | 66 | 16 | 15 | 16 | 43 | 58 | 58 |
| 31. | 98·5 | .... | 98·0 | 58 | .... | .... | 16 | .... | .... | 43 | .... | 55 |
| | 98·7 | 98·2 | 97·9 | 58·9 | 55·2 | 56·5 | 15·7 | 16 | 15·4 | 42 | 47 | 60 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Jan. 1. | 98°·5 | °.... | 97°·5 | 58 | .... | 58 | 16 | .... | 15 | 40° | ° | ° |
| 2. | 98·4 | .... | .... | 54 | .... | .... | 16 | .... | .... | 42 | | |
| 3. | 99·0 | .... | 97·9 | 64 | .... | 58 | 16 | .... | 17 | 42 | .... | 55 |
| 4. | 98·8 | .... | .... | 66 | .... | .... | 17 | .... | 16 | 48 | .... | .... |
| 5. | 99·1 | .... | 98·7 | 64 | .... | 60 | 18 | .... | 15 | 46 | .... | 56 |
| 6. | 99·7 | .... | 98·1 | 70 | .... | 66 | 18 | .... | .... | 48 | .... | 66 |
| 7. | 100·0 | 98·9 | 98·1 | 72 | 60 | 52 | 18 | 17 | 16 | 50 | 58 | 65 |
| 8. | 99·1 | .... | 98·1 | 62 | .... | 56 | 16 | .... | 15 | 49 | .... | 68 |
| 9. | 99·0 | .... | 98·3 | 60 | .... | 60 | 16 | .... | 16 | 46 | .... | 61 |
| 10. | 99·1 | 98·6 | 98·3 | 60 | 58 | 54 | 16 | 15 | 16 | 46 | 53 | 60 |
| 11. | 98·7 | .... | 97·4 | 56 | .... | 58 | 14 | .... | 14 | 47 | .... | 60 |
| 12. | 98·7 | .... | 98·0 | 54 | .... | 60 | 14 | .... | 16 | 47 | .... | 64 |
| 13. | 98·9 | 98·7 | 98·1 | 52 | 60 | 62 | 16 | 14 | 16 | 46 | 53 | 61 |
| 14. | 99·2 | .... | 97·9 | 56 | .... | 60 | 14 | .... | 15 | 46 | .... | 65 |
| 15. | 98·8 | .... | 97·7 | 58 | .... | 56 | 14 | .... | 16 | 47 | .... | 64 |
| 16. | 98·7 | .... | 97·7 | 56 | .... | 60 | 16 | .... | 16 | 47 | .... | 62 |
| 17. | 98·9 | .... | 98·1 | 54 | .... | 60 | 15 | .... | 14 | 47 | .... | 62 |
| 18. | 98·9 | .... | 98·2 | 60 | .... | 58 | 15 | .... | 14 | 47 | .... | 55 |
| 19. | 98·8 | .... | 97·8 | 60 | .... | 56 | 14 | .... | 15 | 47 | .... | 60 |
| 20. | 98·8 | .... | 98·0 | 56 | .... | 54 | 15 | .... | 14 | 44 | .... | 60 |
| 21. | 98·7 | .... | 97·9 | 58 | .... | 62 | 16 | .... | 16 | 44 | .... | 63 |
| 22. | 9·88 | .... | 97·9 | 60 | .... | 50 | 16 | .... | 14 | 47 | .... | 63 |
| 23. | 98·8 | .... | .... | 56 | .... | .... | 16 | .... | .... | 47 | .... | .... |
| 24. | 98·9 | .... | 97·3 | 58 | .... | 54 | 15 | .... | 15 | 49 | .... | 68 |
| 25. | 98·6 | .... | .... | 54 | .... | .... | 15 | .... | .... | 47 | .... | .... |
| 26. | 98·6 | .... | 98·1 | 58 | .... | 62 | 15 | .... | 16 | 48 | .... | 66 |
| 27. | 98·7 | .... | 97·9 | 58 | .... | 54 | 15 | .... | 14 | 45 | .... | 62 |
| 28. | 99·0 | .... | 97·6 | 62 | .... | 58 | 15 | .... | 15 | 43 | .... | 62 |
| 29. | 98·5 | .... | 97·9 | 56 | .... | 56 | 15 | .... | 15 | 42 | .... | 60 |
| 30. | 98·5 | .... | 98·2 | 56 | .... | 58 | 14 | .... | 15 | 41 | .... | 60 |
| 31. | 98·8 | .... | 97·9 | 60 | .... | 62 | 16 | .... | 16 | 38 | .... | 62 |
| | 98·8 | 98·07 | 97·9 | 58·7 | 59·3 | 57·9 | 15·5 | 15·3 | 15·1 | 45 | 55 | 60 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| Feb. 1. | 98°·8 | .... | 97°·5 | 60 | .... | 52 | 16 | .... | 15 | 39° | .... | 62° |
| 2. | 98·5 | 98·7 | .... | 60 | 52 | .... | 16 | 14 | .... | 38 | 48 | |
| 3. | 98·7 | .... | .... | 60 | .... | .... | 16 | .... | .... | 41 | | |
| 5. | 98·6 | .... | .... | 64 | .... | .... | 18 | .... | .... | 44 | | |
| 6. | 98·8 | .... | 97·9 | 56 | .... | 54 | 15 | .... | 15 | 43 | .... | 60 |
| 7. | 98·5 | .... | 98·1 | 56 | .... | 62 | 14 | .... | 15 | 39 | .... | 60 |
| 8. | 98·9 | .... | 98·0 | 52 | .... | 54 | 16 | .... | 16 | 40 | .... | 60 |
| 9. | 98·1 | 98·5 | 97·9 | 52 | 56 | 54 | 14 | 15 | 15 | 38 | 50 | 61 |
| 10. | 98·7 | 98·9 | 97·7 | 54 | 58 | 52 | 16 | 15 | 15 | 40 | 48 | 60 |
| 11. | 98·7 | .... | 97·7 | 56 | .... | 54 | 16 | .... | 15 | 40 | .... | 60 |
| 12. | 98·7 | .... | 98·2 | 50 | .... | 58 | 14 | .... | 16 | 40 | .... | 60 |
| 13. | 98·4 | .... | 98·2 | 50 | .... | 54 | 15 | .... | 15 | 40 | .... | 60 |
| 14. | 98·2 | 98·4 | 97·8 | 50 | 54 | 54 | 17 | 15 | 17 | 41 | 48 | 63 |
| 15. | 98·8 | .... | 97·6 | 54 | .... | 54 | 17 | .... | 15 | 43 | .... | 60 |
| 16. | 98·6 | 98·7 | 98·1 | 54 | 52 | 52 | 15 | .... | 16 | 43 | 48 | 62 |
| 17. | 98·5 | .... | 98·2 | 54 | .... | 50 | 16 | 16 | 15 | 44 | .... | 60 |
| 18. | 99·0 | .... | 98·2 | 58 | .... | 56 | 16 | .... | 15 | 45 | .... | 60 |
| 19. | 98·7 | .... | 97·7 | 56 | .... | 48 | 15 | .... | 15 | 44 | .... | 60 |
| 20. | 98·7 | .... | .... | 52 | .... | .... | 15 | .... | .... | 45 | | |
| 21. | 98·8 | .... | 98·1 | 52 | .... | 58 | 14 | .... | 15 | 45 | .... | 60 |
| 22. | 99·0 | .... | 97·4 | 60 | .... | 60 | 15 | .... | 15 | 44 | .... | 62 |
| 23. | 98·6 | .... | 98·3 | 58 | .... | 52 | 15 | .... | 15 | 43 | .... | 62 |
| 24. | 98·3 | .... | 97·8 | 58 | .... | 54 | 16 | .... | 16 | 42 | .... | 62 |
| 25. | 99·0 | .... | 97·9 | 56 | .... | 50 | 15 | .... | 15 | 43 | .... | 62 |
| 26. | 98·3 | .... | 98·0 | 56 | .... | 60 | 16 | .... | 14 | 46 | .... | 62 |
| 27. | 99·0 | .... | 97·8 | 58 | .... | 52 | 16 | .... | 14 | 47 | .... | 62 |
| 28. | 98·7 | .... | 98·5 | 54 | .... | 60 | 15 | .... | 15 | 47 | .... | 60 |
| | 98·6 | 98·6 | 97·9 | 55·5 | 54·4 | 52·3 | 15·5 | 15 | 15·1 | 42 | 48 | 61 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| March 1. | 99°·0 | 98°·6 | 97°·6 | 58 | 56 | 58 | 16 | 16 | 16 | 45° | 52° | 60° |
| 2. | 99·1 | 98·7 | 97·9 | 58 | 52 | 46 | 16 | 15 | 16 | 44 | 55 | 60 |
| 3. | 98·5 | .... | 98·5 | 52 | .... | 56 | 15 | .... | 15 | 47 | .... | 60 |
| 4. | 99·0 | 98·3 | 98·0 | 60 | 54 | 54 | 15 | 16 | 15 | 45 | 52 | 60 |
| 5. | 98·6 | .... | 98·0 | 58 | .... | 66 | 17 | .... | 15 | 43 | .... | 60 |
| 6. | 99·0 | .... | 98·2 | 60 | .... | 54 | 16 | .... | 15 | 43 | .... | 60 |
| 7. | 99·0 | .... | 98·0 | 60 | .... | 64 | 14 | .... | 15 | 44 | .... | 62 |
| 8. | 99·2 | .... | 98·1 | 60 | .... | 60 | 16 | .... | 15 | 46 | .... | 60 |
| 9. | 99·1 | 98·7 | 98·0 | 60 | 48 | 54 | 15 | 15 | 15 | 48 | 54 | 58 |
| 10. | 99·0 | .... | 97·5 | 60 | .... | 54 | 16 | .... | 15 | 48 | .... | 60 |
| 11. | 98·8 | .... | 97·9 | 56 | .... | 48 | 15 | .... | 14 | 47 | .... | 58 |
| 12. | 98·4 | .... | 97·7 | 54 | .... | 56 | 16 | ... | 14 | 47 | .... | 61 |
| 13. | 98·8 | .... | 98·2 | 60 | .... | 54 | 15 | .... | 15 | 43 | .... | 61 |
| 14. | 98·6 | .... | 97·9 | 54 | .... | 46 | 14 | .... | 14 | 44 | .... | 58 |
| 15. | 98·2 | .... | 97·5 | 54 | .... | 60 | 14 | .... | 14 | 42 | .... | 62 |
| 16. | 98·7 | .... | 98·1 | 58 | .... | 62 | 15 | .... | 14 | 43 | .... | 58 |
| 17. | 98·6 | .... | 98·0 | 60 | .... | 52 | 15 | .... | 15 | 40 | .... | 58 |
| 18. | 98·5 | 98·7 | 98·0 | 62 | 58 | 48 | 15 | 15 | 15 | 43 | 53 | 60 |
| 19. | 98·5 | .... | 98·4 | 56 | .... | 54 | 14 | .... | 15 | 43 | .... | 58 |
| 20. | 98·6 | .... | 97·5 | 54 | .... | 54 | 15 | .... | 15 | 42 | .... | 60 |
| 21. | 98·8 | 98·6 | 98·1 | 54 | 50 | 50 | 14 | 14 | 14 | 44 | 53 | 60 |
| 22. | 99·0 | 98·5 | 97·8 | 56 | 54 | 54 | 15 | 15 | 13 | 48 | 58 | 60 |
| 23. | 99·0 | .... | 97·8 | 58 | .... | 52 | 15 | .... | 14 | 50 | .... | 61 |
| 24. | 98·7 | .... | 98·0 | 58 | .... | 48 | 15 | .... | 13 | 53 | .... | 58 |
| 25. | 98·4 | .... | 98·0 | 54 | .... | 48 | 14 | .... | 14 | 52 | .... | 60 |
| 26. | 98·4 | .... | 98·2 | 54 | .... | 60 | 15 | .... | 15 | 51 | .... | 62 |
| 27. | 98·8 | .... | 97·8 | 60 | .... | 52 | 15 | .... | 16 | 52 | .... | 64 |
| 28. | 98·7 | .... | 98·3 | 54 | .... | 54 | 16 | .... | 15 | 50 | .... | 64 |
| 29. | 98·7 | .... | 97·3 | 56 | .... | 54 | 14 | .... | 14 | 50 | .... | 65 |
| 30. | 98·6 | 98·6 | 97·8 | 55 | 52 | 48 | 15 | 15 | 15 | 51 | 54 | 62 |
| 31. | 98·6 | .... | 97·5 | 54 | .... | 54 | 15 | .... | 15 | 51 | .... | 63 |
| | 98·74 | 98·59 | 97·93 | 57 | 53 | 54 | 15·1 | 15·1 | 15 | 46 | 54 | 60 |

| Date. | Temperature under the tongue. | | | Pulse. | | | Respirations. | | | Temperature of air. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. | 7–8 A.M. | 3–4 P.M. | 12 P.M. |
| April 1. | 98°·3 | .... | 98°·0 | 58 | .... | 58 | 16 | .... | 15 | 53° | .... | 62° |
| 2. | 98·7 | 98·8 | 97·7 | 58 | 58 | 52 | 15 | 16 | 15 | 53 | 62 | 64 |
| 3. | 98·8 | .... | 97·7 | 56 | .... | 48 | 15 | .... | 14 | 55 | .... | 62 |
| 4. | 98·8 | .... | 97·8 | 54 | .... | 60 | 15 | .... | 14 | 58 | .... | 64 |
| 5. | 98·9 | .... | 98·1 | 60 | .... | 64 | 15 | .... | 16 | 58 | .... | 64 |
| 6. | 99·3 | 98·8 | 97·9 | 62 | 60 | 50 | 15 | 15 | 15 | 55 | 61 | 62 |
| 7. | 98·8 | 98·8 | 98·2 | 54 | 56 | 56 | 14 | 15 | 16 | 58 | 61 | 63 |
| 8. | 98·5 | .... | 97·9 | 56 | .... | 56 | 15 | .... | 15 | 58 | .... | 61 |
| 9. | 98·6 | .... | 98·1 | 60 | .... | 58 | 14 | .... | 15 | 54 | .... | 62 |
| 10. | 98·5 | 98·3 | 98·0 | 62 | 52 | 62 | 14 | 14 | 15 | 52 | 52 | 63 |
| 11. | 98·7 | .... | 97·6 | 60 | .... | 54 | 14 | .... | 15 | 51 | .... | 63 |
| 12. | 98·4 | .... | 97·9 | 56 | .... | 50 | 15 | .... | 15 | 49 | .... | 59 |
| 13. | 98·5 | 98·7 | 97·6 | 54 | 54 | 54 | 15 | 15 | 15 | 49 | 55 | 60 |
| 14. | 98·7 | .... | 98·0 | 56 | .... | 54 | 15 | .... | 14 | 52 | .... | 60 |
| 15. | 98·6 | 98·8 | .... | 56 | 60 | .... | 15 | 14 | .... | 49 | 58 | |
| 16. | 98·4 | .... | 97·7 | 58 | .... | 52 | 15 | .... | 15 | 52 | .... | 62 |
| 17. | 98·8 | .... | 97·8 | 56 | .... | 50 | 15 | .... | 14 | 56 | .... | 58 |
| 18. | 98·4 | 98·8 | 98·1 | 60 | 54 | 54 | 15 | 15 | 15 | 60 | 60 | 66 |
| 19. | 98·7 | 98·6 | 97·6 | 60 | 52 | 50 | 15 | 16 | 15 | 58 | 60 | 62 |
| 20. | 98·7 | .... | 98·3 | 58 | .... | 54 | 15 | .... | 15 | 60 | .... | 64 |
| 21. | 98·7 | .... | 97·3 | 58 | .... | 56 | 16 | .... | 13 | 60 | .... | 62 |
| 22. | 98·4 | 98·1 | 98·0 | 60 | 56 | 50 | 16 | 15 | 15 | 62 | 65 | 64 |
| 23. | 98·5 | .... | 97·7 | 56 | .... | 54 | 15 | .... | 15 | 62 | .... | 62 |
| 24. | 98·7 | 98·2 | 97·7 | 58 | 52 | 52 | 16 | 16 | 15 | 64 | 64 | 65 |
| 25. | 98·6 | 98·4 | 97·9 | 64 | 52 | 52 | 16 | 15 | 16 | 65 | 63 | 62 |
| 26. | 99·0 | .... | 98·0 | 58 | .... | 50 | 15 | .... | 14 | 62 | .... | 62 |
| 27. | 98·8 | 98·8 | 97·9 | 54 | 52 | 50 | 15 | 14 | 15 | 60 | 57 | 63 |
| 28. | 98·6 | .... | .... | 58 | .... | .... | 16 | .... | .... | 58 | | |
| 29. | .... | 98·3 | 98·2 | .... | 54 | 52 | .... | 15 | 15 | .... | 60 | 64 |
| 30. | 98·9 | 98·7 | 98·2 | 58 | 56 | 48 | 14 | 15 | 14 | 58 | 58 | 65 |
| | 98·66 | 98·57 | 97·88 | 56·5 | 54·8 | 53·6 | 15·4 | 15 | 14·8 | 54·6 | 59·8 | 62·4 |

# XV. *Contributions to the Chemistry of the Urine. On the Variations in the Alkaline and Earthy Phosphates in the Healthy State, and on the Alkalescence of the Urine from Fixed Alkalies.* By Henry Bence Jones, *M.A., Cantab., Fellow of the College of Physicians. Communicated by* S. Hunter Christie, *Esq., Sec. R.S.*

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## *On the Variations of the Earthy and Alkaline Phosphates in a healthy state of Urine.*

HAVING observed the occurrence of a great excess of earthy phosphates in the urine in some cases of disease, and having made frequent examinations as to the quantity present on successive days, I found so great a discrepancy, that it became necessary before any further progress could be made to ascertain the variations in the amount of earthy phosphates in the urine of a healthy man, and, if possible, to trace the causes which determined the presence of an excess or deficiency of these salts in the urine. At the same time it was thought desirable to note the variations which the alkaline phosphates presented in the same water, and to see if they were influenced by the same, or by different causes.

A healthy man taking food twice daily, with moderate exercise for three hours, was the subject of the following experiments. The method followed was to take the specific gravity of the urine, if ever it was not strongly acid adding a drop or two of hydrochloric acid. Then from a weighed quantity, usually about 1000 grains, to precipitate the earthy phosphates by means of pure ammonia, to filter, wash with ammoniacal water, and heat them to redness, adding at last a drop or two of nitric acid. Thus the earthy phosphates were determined.

The alkaline phosphates were estimated by taking usually about 500 grains of urine, adding an excess of chloride of calcium and then pure ammonia; by this means all phosphoric acid was precipitated as phosphate of lime; this was filtered, well-washed, and heated to redness with nitric acid; by deducting the previously determined earthy phosphates, the difference was considered as alkaline phosphate*.

Though neither the calculation nor the method were perfectly accurate, yet they answered well for the purposes of comparison; and in disease the short delay before a result was arrived at which might determine the diagnosis, and sometimes the treatment, was a matter of considerable importance; a few hours being usually all that were required to tell in what excess or deficiency the phosphates might be present.

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* The formation of a small quantity of carbonate of ammonia and the precipitation of some sulphate of lime, which even long washing cannot entirely remove, make the result too high. The equivalent of lime being less than that of soda tends to reduce the error. It must be remembered that the phosphoric acid is precipitated in combination with three equivalents of lime.

I. (1.) Breakfast on bread and meat with coffee at 9½ o'clock. Dinner at 6: meat, potatoes, and little bread.

| | | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|---|
| Water passed | 6 o'clock, evening | ·32 per 1000 urine | 1022·8 | 6·50 per 1000 urine. |
| | 10 o'clock, evening | ·97 | 1027·3 | 5·45 |
| | 6 o'clock, morning | ·81 | 1017·4 | 4·01 |
| (2.) Food as before. More exercise. Dinner at 7. | | | | |
| | 7 o'clock, evening | ·37 | 1027·2 | 7·26 |
| | 11 o'clock, evening | 1·22 | 1029·9 | 6·06 |
| | 5 o'clock, morning | 1·41 | 1025·5 | 3·64 |
| (3.) Food as before. Still more exercise. | | | | |
| | 7 o'clock, evening | ·75 | 1028·0 | 8·10 |
| | 12 at night | 1·29 | 1025·5 | 6·67 |
| (4.) Food as before. Exercise very great excess. | | | | |
| | 7 o'clock, evening | ·21 | 1028·2 | 8·22 |
| | 1 at night | 1·85 | 1034·3 | 5·94 |
| (5.) Food as before. Exercise much less. | | | | |
| | 7 o'clock, evening | ·35 | 1029·3 | 7·75 |
| | 1 at night | 1·91 | 1033·2 | 4·72 |

| Average mean of five days. | Long after food, and soon after exercise. | Spec. gr. | Soon after food with perfect rest. | Spec. gr. |
|---|---|---|---|---|
| Earthy phosphates | ·40 per 1000 urine | 1027·9 | 1·45 per 1000 urine | 1030·0 |
| Alkaline phosphates | 7·56 | 1027·9 | 5·77 | 1030·0 |

From this five days' experiment, it appears that the earthy phosphates are greatly increased in the water secreted soon after food; the quantity varying after dinner from 1·91 per 1000 urine, specific gravity 1033·2, to ·97 per 1000 urine, specific gravity 1027·3; the mean of all the experiments being 1·45 per 1000 urine, specific gravity 1030·0.

The earthy phosphates are far less in the water secreted a long time after food; the quantity varying from ·21 per 1000 urine, specific gravity 1028·2, to ·75 per 1000 urine, specific gravity 1028·0; the mean of all the experiments being ·40 per 1000 urine, specific gravity 1027·9.

The alkaline phosphates are in excess in the water secreted a long time after food and soon after exercise; the quantity varying from 8·10 per 1000 urine, specific gravity 1028·0, to 6·50 per 1000 urine, specific gravity 1022·8; the mean of all the experiments being 7·56 per 1000 urine, specific gravity 1027·9.

The alkaline phosphates are far less in the water secreted soon after food; the quantity varying from 6·67 per 1000 urine, specific gravity 1025·5, to 4·72 per 1000 urine, specific gravity 1033·2; the mean of all the experiments being 5·77 per 1000 urine, specific gravity 1030·0.

(6.) A child twenty months old, fed on bread with some meat and milk, gave in the water passed during the day,—

| Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|
| ·32 per 1000 urine. | 1012·2 | 4·00 per 1000 urine. |

(7.) On the same food.

| Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|
| ·33 per 100 urine. | 1017·4 | 4·60 per 1000 urine. |

II. I next endeavoured to ascertain on what the variations depended, and first with regard to food. For three consecutive days bread alone was taken with water, tea and wine, at the same hours as in the previous experiments.

(8.) The first day brown bread only.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 5½ o'clock, evening | ·27 per 1000 urine | 1025·7 | 7·89 per 1000 urine |
| 11 at night. | 1·37 | 1030·0 | 6·39 |

(9.) The second day no analysis was made. The third day white bread only.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 6 o'clock, evening | ·37 per 1000 urine | 1024·7 | 8·19 per 1000 urine |
| 11 o'clock, evening | 1·86 | 1032·1 | 5·56 |

(10.) Meat only was taken for three days with water, wine, and tea. First day exercise very little.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 6 o'clock, evening | ·42 per 1000 urine | 1024·3 | 4·04 per 1000 urine |
| 11 o'clock, evening | 1·11 | 1021·9 | 4·21 |

(11.) The second day no analysis was made. The third day exercise rather more.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 6 o'clock, evening | ·48 per 1000 urine | 1024·7 | 5·06 per 1000 urine |
| 11 o'clock, evening | ·81 | 1024·8 | 4·31 |

(12.) Meat only for dinner with distilled water, and tea with distilled water.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 5½ o'clock, evening | ·33 per 1000 urine | 1025·7 |
| 9½ o'clock, evening | ·67 | 1026·5 |

From the comparison of these numbers with the previously given average, it appears that the earthy phosphates are not materially influenced by a diet of meat or diet of bread; that they are in excess after either is taken; and that even when animal food and distilled water alone were taken there was after food a decided increase, though the quantity was considerably below the average.

That the alkaline phosphates were in excess when bread alone was taken for food; and when meat alone was taken there was a considerable falling off in the amount excreted.

The next point was the effect of exercise.

(13.) Nothing was taken from dinner on the previous day to dinner this day; both meals consisted of mixed diet of meat, bread, and potatoes. The exercise was moderate, between three and six o'clock.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 12½ o'clock | ·45 per 1000 urine | 1025·1 | 2·95 per 1000 urine |
| 3 o'clock | ·48 | 1026·0 | 2·92 |
| 6 o'clock | | 1027·1 | total phos. per 1000 urine 4·77 |
| 10½ at night | 1·02 | 1027·6 | 3·99 |

(14.) Nothing was taken since dinner on the previous day until dinner at six; mixed diet with more bread. Exercise also greater between 3 and 5½ o'clock.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 3 o'clock | ·36 per 1000 urine | 1025·4 | 5·69 |
| 6 o'clock | | 1027·1 | total phos. per 1000 urine 7·78 |
| 10½ at night | 1·37 | 1032·5 | 5·50 |

(15.) Nothing was taken since dinner on the previous day, which consisted of meat only, with distilled water and wine. Very strong exercise was taken between 3 and 5½, the pulse always above 100.

| | Earthy phosphates. | Spec. gr. | Alkaline phosphates. |
|---|---|---|---|
| 11½ o'clock | ·52 per 1000 urine | 1022·9 | 3·04 |
| 3 o'clock | ·36 | 1026·9 | 4·36 |
| 5½ o'clock | | 1028·9 | total phos. per 1000 urine 6·81 |

In these experiments, the water, which was secreted longest after food, was not in sufficient quantity to admit of the determination of the earthy as well as alkaline phosphates. In all the experiments which were previously made, the exercise was always most between 3 and 6 o'clock, and yet at this time the earthy phosphates were always present in smallest quantity; so that the quantity of earthy phosphates does not appear to be quickly influenced by exercise.

The total quantity of phosphates which was found in the water secreted longest after food, and during strong exercise, was about one-third more than the total quantity previously present. This considerable increase so long after food, leads to the conclusion that the amount of alkaline phosphates is influenced by exercise, though, as appears from the previous experiments, not to the same extent as by the kind of food which is taken.

III. I pass now to the influence of different medicinal substances on the amount of earthy phosphates excreted.

(16.) Breakfast as before, at 9 o'clock. 15 grains of chloride of calcium taken in about an ounce of distilled water at 3 o'clock.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 3 o'clock | ·30 per 1000 urine | 1024·6 |
| 5½ o'clock | ·22 | 1016·4 |

(17.) Experiment repeated.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 3 o'clock | ·67 per 1000 urine | 1024·4 |
| 5½ o'clock | ·52 | 1020·8 |

(18.) Breakfast, bread only. 22 grains of chloride of calcium taken at ¼ to 1 o'clock.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| ¼ to 1 o'clock | 1·18 per 1000 urine | 1028·6 |
| 3 o'clock | 1·08 | 1025·2 |

(19.) Breakfast, bread and meat. 35 grs. of chloride of calcium in 1½ ounce of water at ¼ to 1.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| ¼ to 1 o'clock | 1·23 per 1000 urine | 1026·8 |
| 3 o'clock | 1·26 | 1023·8 |
| 5½ o'clock | 1·08 | 1022·3 |
| 10¼ at night | 1·82 | 1030·1 |

(20.) Breakfast, bread and meat. No chloride of calcium taken. Dinner as before at 6, chiefly meat.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 3 o'clock | ·60 per 1000 urine | 1027·4 |
| 6 o'clock | ·36 | 1027·0 |
| 11 at night | ·97 | 1032·7 |

From these experiments 15 grs. of chloride of calcium in an ounce of water produced no, or very little, effect in two hours and a half; 22 grs. in rather more water produced an increase in two hours and a quarter; 30 grains produced a still more marked increase in the same time, and the effect continued to be perceptible for at least ten hours.

(21.) Breakfast as before, with rather more meat. 30 grains of dry sulphate of magnesia were taken at 1 o'clock in about an ounce and a half of distilled water.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 1 o'clock water | ·82 per 1000 urine | 1026·6 |
| 3 o'clock water | ·27 | 1026·0 |
| 5¼ o'clock water | ·36 | 1025·8 |

(22.) Breakfast at 9 as formerly. 40 grains of dry sulphate of magnesia taken in about two ounces and a half of water at a ¼ to 1 o'clock.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| ¼ to 1 o'clock water | ·88 per 1000 urine | 1029·3 |
| 3 o'clock water | ·74 | 1031·0 |
| 5½ o'clock water | ·90 | 1029·3 |
| 9½ o'clock water | 1·64 | 1032·3 |

(23.) A patient of Dr. Seymour's in St. George's Hospital had taken senna with about two drachms of sulphate of magnesia in the morning, which did not act on the bowels; at 12 beef-tea and bread.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 3 o'clock | 2·99 per 1000 urine | 1027·6 |

A second experiment with the same urine, at the same time, gave nearly the same result; the alkaline phosphates were only 1·45 per 1000 urine, specific gravity 1027·6.

(24.) Another patient of Dr. SEYMOUR's in St. George's Hospital, who had taken senna and salts in the morning, with beef-tea and arrow-root for dinner, gave

| Earthy phosphates. | Spec. gr. |
|---|---|
| 2·93 per 1000 urine | 1026·2 |

The quantity of sulphuric acid present in this urine

=3·21 per 1000 urine, specific gravity 1026·2

The amount given by BECQUEREL is = ·95 1018·9

The quantity stated by BECQUEREL is however below the average.

From these experiments, 30 grains of dry sulphate of magnesia in an ounce and a half of water produced no, or very little, effect in two hours. In four hours and a quarter the effect was distinctly visible. 40 grains in two ounces and a half of water produced a visible effect in two hours and a quarter, and a still more marked effect in four hours and three quarters. The effect continued to be perceptible for 9¾ hours after the medicine was taken.

As compared with the previous experiments, though the quantity taken appears to have been more, the effects seem not to have been so strongly marked; but in fact less of the base was taken in the last than in the previous set of experiments, for

30 grains of chloride of calcium are equivalent to 15·1 grains of lime,

40 grains of sulphate of magnesia are equivalent to 13·6 grains of magnesia.

As sulphate of magnesia is one cause of increase in the amount of earthy phosphates precipitated by ammonia, and as this salt also interferes in analyses regarding the quantity of sulphuric acid which is thrown out of the system, any means of knowing when it has been given as a medicine may be valuable. Most frequently it is prescribed with infusion of senna, which communicates a greenish yellow colour to the urine. This colouring matter, whether it has passed through the system or not, I find has the property of becoming of a deep red on the addition of an excess of any alkali, though it is most bright with ammonia. The red colour disappears again on neutralizing the alkali by an acid. It has a strong affinity for phosphate of lime. If rhubarb is taken, a less bright colour is given by the same reagents. I have lately found that Sir E. HOME in some of his experiments on absorption used the reaction of potash on tincture of rhubarb because it is so remarkable*.

(25.) Breakfast as before. 45 grains of dry magnesia taken at 10 o'clock. It had no action at all on the bowels.

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* Philosophical Transactions, 1808, p. 45. According to the researches of SCHLOSSBERGER, this reaction is caused by chrysophanic acid which exists in the rhubarb.—Annalen der Chemie, vol. l. p. 214.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 11¼ o'clock, water acid | ·90 per 1000 urine | 1026·7 |
| ¼ to 1 o'clock, water alkaline | ·69 | 1027·8 |
| 3 o'clock, water alkaline | 1·19 | 1029·6 |
| 5½ o'clock, water very acid | 1·48 | 1028·0 |
| 10 o'clock, water very acid | 2·69 | 1032·8 |

(26.) Breakfast as before. 30·8 grains of magnesia taken at ¼ to 1. It did not act on the bowels.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| ¼ to 1 o'clock, water acid | 1·79 per 1000 urine | 1030·4 |
| 3 o'clock, water acid | 1·19 | 1032·2 |
| 4<br>5½ } o'clock, both acid | 1·69 | 1032·3 |
| 9½ o'clock, water very acid | 2·44 | 1034·5 |

(27.) Breakfast as before. No magnesia taken.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 3 o'clock | 1·00 per 1000 urine | 1030·3 |
| 6 o'clock | ·59 | 1031·4 |
| 9½ o'clock | 1·39 | 1031·6 |

Hence 45 grains of magnesia produced no increase in the phosphates in two hours and three quarters; in five hours there was a marked increase; in seven and a half hours there was a still further increase, which was very marked at the end of twelve hours, and from the large quantity of earthy phosphates present the following morning, perhaps the magnesia had not ceased to act in twenty-four hours.

30·8 grains of magnesia produced no evident increase in two hours and a quarter; in four hours and three quarters the increase was marked, and after eight hours and three quarters it was quite perceptible. From the analysis of the urine after twenty-six hours, it seems probable that the magnesia had not then ceased to influence the amount of earthy phosphates.

(28.) Water of the same child as (6.) and (7.) 15·4 grains of magnesia taken about 7½ o'clock. Did not operate until after last water was passed. Food as before.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 11 to 1 o'clock, water alkaline | ·62 per 1000 urine | 1025·3 |
| 3 to 5 o'clock, water acid | 1·57 per 1000 urine | 1027·7 |

(29.) Same child. Food as before. No magnesia.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 2 to 5 o'clock, water acid | ·36 per 1000 urine | 1018·5 |

(30.) Same child. 19·3 grains of magnesia at 8 o'clock. Medicine acted about three o'clock.

| | Earthy phosphates. | Spec. gr. |
|---|---|---|
| 11 to 1 o'clock, water neutral | ·45 per 1000 urine | 1014·4 |
| 3 to 5 o'clock, water acid | ·80 | 1017·1 |

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The conclusions from these experiments are—

I. As regards variation in the phosphates.

The earthy phosphates soon after food were found to vary from 1·91 per 1000 urine, specific gravity 1033·2, to ·97 per 1000 urine, specific gravity 1027·3.

Long after food they vary from ·21 per 1000 urine, specific gravity 1028·2 to ·75 per 1000 urine, specific gravity 1028·0.

The alkaline phosphates long after food, and soon after exercise, vary from 8·10 per 1000 urine, specific gravity 1028·0, to 6·50 per 1000 urine, specific gravity 1022·8.

Long after food the quantity varies from 6·67 per 1000 urine, specific gravity 1025·5, to 4·72 per 1000 urine, specific gravity 1033·2.

II. As to the causes of the variation.

(*a.*) As regards food.

The earthy phosphates were not materially influenced by a diet of meat or of bread. They were in excess after either was taken; but on distilled water and meat alone, the excess was considerably below the average.

A long time after food the earthy phosphates were greatly diminished.

The alkaline phosphates were present in greatest quantity when bread alone was taken for food; when meat alone was taken, the deficiency was more marked than the excess with bread alone was. There was the most marked difference when the bread diet was compared with the meat diet.

(*b.*) As regards exercise.

Exercise produced no marked effect on the earthy phosphates.

On the alkaline phosphates exercise caused an increase of nearly one-third the amount previously excreted. This difference is not so great as that between bread and meat diets; so that probably though exercise has some influence, the kind of diet has a greater influence.

III. As to the effect of medical substances on the earthy phosphates.

(*a.*) As regards chloride of calcium.

15 grains of chloride of calcium produced no, or very little, effect in two hours and a half.

22 grains in rather more water produced a very decided increase in two hours and a quarter.

30 grains produced a still more marked increase in the same time, and the effect continued to be perceptible for ten hours.

(*b.*) As regards sulphate of magnesia.

30 grains of sulphate of magnesia in 1½℥ water produced no, or very little, effect in two hours; in four hours and a quarter an increase was distinctly visible.

40 grains in 2¼℥ of water produced a very slight effect in two hours and a quarter; in 4¾ hours an increase was very distinct, and continued to be perceptible for nine hours.

(*c.*) As regards calcined magnesia.

45 grains of magnesia produced no effect in two hours and three quarters; in five hours there was a marked increase; in seven hours and a half a still greater increase, which was very marked at the end of twelve hours, and possibly continued for twenty-seven hours to influence the amount of earthy phosphates.

30·8 grains of magnesia produced no increase in two hours and a quarter; in four hours and three quarters the increase was very evident; and after eight hours and three-quarters it was still very marked; and after even twenty-six hours it still increased the amount of earthy phosphates in the urine.

These last experiments give the explanation of the rapid increase of phosphatic calculi, and of the enormous quantities of earthy matter discharged, when magnesia or lime-water have been taken in calculous affections. They show that these substances, having probably combined with different acids, pass off by the urine, and when this latter is alkaline react on the phosphate of soda, and thus increase considerably the amount of earthy phosphates in the deposit.

The result of these experiments is, that the amount of earthy phosphates precipitable by ammonia, depends chiefly on the amount of earthy matter taken into the body; and that the amount of alkaline phosphates is also most chiefly influenced by diet; yet that there is an additional cause constantly acting in the state of health, namely the production of phosphoric acid by the changes in the tissues of the body. And as in disease some of these tissues may be more particularly engaged, so then may the amount of alkaline phosphates point out the character, and declare the nature of the structure which is the seat of the affection.

### *On Alkalescence of the Urine from fixed Alkali.*

The cases in which the urine is alkaline may be divided into two classes. In the one the alkalescence arises from volatile alkali, and in the other from fixed alkali. In the first it is caused by carbonate of ammonia, and in the second by carbonate of soda, or potash, or alkaline phosphate of soda. Decomposition of urea is the origin of the one, and disordered secretion of the other.

Whenever alkalescence arises, the earthy phosphates, whatever their quantity, are generally precipitated; and hence the expression phosphatic diathesis, a term which makes no distinction between the different kinds of alkalescence, nor between cases in which the earthy phosphates, sometimes far below their average quantity, simply appear in consequence of their insolubility in alkaline fluids, and cases in which a vast excess of earthy or alkaline phosphates is being excreted.

The object of the present paper is to point out the fact and the value of the distinction between the different kinds of alkalescence.

M. **Pelouze** has shown how rapidly decomposing mucus effects the conversion of urea into carbonate of ammonia. Irritation of the mucous membrane may give rise to mucus which produces this change, and in consequence the blue colour will be restored to reddened litmus paper if dipped into urine containing such mucus; or if blue paper be used, this, whilst wet, will retain its colour; but if the test-paper be left to dry in either case it will be found that a change takes place. From the reddened litmus paper first used the blue colour will disappear, whilst the blue paper, when quite dry, will become red in consequence of a slight decomposition of the ammoniacal salt. This decomposition I have elsewhere shown to be the result of the evaporation of all ammoniacal solutions, and thus a ready and easy way is afforded of determining in any case of the alkalescence of the urine, whether it is caused by some ammoniacal salt, or whether it results from the presence of some fixed alkali*.

It not unfrequently happens that alkalescence is caused by fixed alkaline salts in those who, though not ill, yet suffer from indigestion whilst leading sedentary lives. I have more especially observed it where the octahedral crystals, usually supposed to be oxalate of lime, have been present. After a breakfast consisting chiefly of bread, in an hour and a half the water passed may be found healthily acid to test-paper, but that which is next passed, that is, from two to four hours after breakfast, will have an alkaline reaction. Frequently blue test-paper will be found, when dry, to undergo no change from the action of such urine. It will remain of nearly as deep a blue as before when the fluid has perfectly evaporated. This urine when passed will, though alkaline, often be perfectly clear, and if it be heated a granular precipitate will fall, the fluid becoming turbid from the deposit of earthy phosphates, which dissolve in dilute hydrochloric acid, usually without any effervescence.

Such a precipitation by heat takes place when the urine is not even neutral. It may be slightly acid. When boiled a precipitate falls, and if the fluid is then tested it is found to be more acid than before. If such a deposit from acid urine is left to become cold, the earthy phosphates are found to be partially, and sometimes even entirely redissolved, being again precipitable by boiling, and again partially or entirely dissolving on cooling.

If such urine as I have mentioned is passed alkaline and thick from deposit, it will be found, if immediately examined by the microscope, to be entirely granular (Plate V. fig. 2), the supposed form of phosphate of lime. Dilute hydrochloric acid, if added occasionally causes an effervescence, which in some cases arises from some alkaline carbonate in solution.

If the alkalescent or neutral urine is left for some hours, the surface becomes covered with an iridescent pellicle (fig. 1). This examined with the microscope contained here and there a long prismatic crystal, but the pellicle itself consisted of plates covered with spots of amorphous deposit. Some of these were triangular, some quadrilateral, some with regular and others with a ragged margin. The iridescence depended on these plates, which probably consist of phosphate of lime, as in some cases not a single prismatic crystal has been visible.

In some who suffer from indigestion the deposit of amorphous phosphate is constantly seen about three hours after breakfast, and very rarely at other times. In others the alkalescence of the urine is frequently observed, but the deposit is rare; whilst in others the deposit by heat from acid urine is very frequently to be found; and alkalescence is seldom to be detected by test-paper in the water secreted from two to four hours after food, and these three states often alternately occur in the same case.

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* This method, however, I have found to fail when much urate of ammonia and only a small quantity of fixed alkali chanced to be present.

Dr. ANDREWS of Belfast stated to me, that having observed a case otherwise in perfect health, in which the urine was almost invariably alkaline about two hours after breakfast, so much so as frequently to be loaded with a deposition of phosphates whilst still in the bladder, he was led to observe the urine of about fifteen students in good health immediately after it was voided about noon. He found it to be alkaline in about two-thirds of the cases. Whether this tendency to alkalescent urine may, as Dr. ANDREWS thinks, be connected with the immunity enjoyed by the inhabitants of his district from calculous affections, or whether alkalescence at this period of the day is far more general everywhere than has been supposed, future observations must determine.

At the present time I know five physicians in whom the above phenomena at this period of the day are more or less frequently visible in a greater or lesser degree; and in London this alkalescence will be found in those who are considered generally healthy much oftener than is imagined.

Supposing that acid phosphate of soda was the cause of the acid reaction of healthy urine, it was thought that some explanation of the deposit on boiling might be gained by observing the behaviour of phosphate of lime and phosphate of magnesia with phosphate and biphosphate of soda. Pure solutions of these salts and of chloride of calcium, and sulphate of magnesia were used, and the following results obtained. The deposits were examined with a magnifying power of 320 times.

Chloride of calcium gave no immediate precipitate with a strong solution of acid phosphate of soda. If left to stand many hours, a crystalline precipitate formed (fig. 3). When boiled no cloudiness was observed, if the quantity of phosphate of lime present was small; but if much was in solution, a crystalline precipitate fell on boiling; and when cold, if filtered and again boiled, a very small crystalline precipitate was occasioned, which did not entirely redissolve on cooling.

When a solution of biphosphate of soda is mixed with chloride of calcium, an immediate precipitate is caused by a drop or two of any alkali, and this is crystalline (fig. 3), or granular (fig. 2), or these mixed according to the quantity of alkali added, that is, according as much or little of the acidity of the solution is removed.

If this precipitate was separated by filtration and the clear liquid boiled, a deposit fell which was at first gelatinous (fig. 2), the fluid becoming more acid to test-paper. The precipitate, if the solution was very acid, changed into the crystalline form (fig. 3), and partly dissolved on cooling.

If chloride of calcium was added to common phosphate of soda, a plentiful granular precipitate fell (fig. 2). This remained granular or changed into the crystalline form (fig. 3), according as the phosphate of soda was or was not in excess. If the chloride of calcium was added in excess, the fluid became acid to test-paper; the precipitate was at first gelatinous, but changed after some hours into crystalline, the fluid becoming less acid after some time. If phosphate of soda was in excess, the precipitate remained of a mixed granular and crystalline appearance, containing some crystals but more granular phosphate of lime (fig. 4).

If common phosphate of soda was poured drop by drop into chloride of calcium, a precipitate fell, which was at first gelatinous (fig. 2), the fluid becoming strongly acid to test-paper; if left to stand, the precipitate became crystalline (fig. 3), and at length lost some or all its acid reaction, which it reacquired again on boiling.

If common phosphate of soda was dropped into solution of nitrate of lime in excess, the result was the same gelatinous granular precipitate first forming, the same acid reaction, and the same change into the crystalline form on standing.

If any of these precipitates were separated by filtration, and the clear liquid boiled, a further slight precipitation occurred, which was granular (fig. 2). If the phosphate of soda was not in excess, the boiling caused an increase in the acid reaction of the liquid. The precipitate which falls when chloride of calcium is added to phosphate of soda, completely dissolves in solution of biphosphate of soda. Such a solution, if heated, gave a plentiful precipitate when boiled; this was granular, and partly dissolved on cooling; but if a great excess of biphosphate of soda was added, the precipitate was much less, and crystalline; and if filtered, but little precipitate again fell on boiling.

If sulphate of magnesia was added to a solution of biphosphate of soda, no precipitate fell; nor on boiling did any change occur. If but little alkali was added, no precipitation occurred on boiling; if rather more, a small, highly crystalline precipitate fell (fig. 5); if still more, heat threw down a plentiful gelatinous granular mass (fig. 2), which most rapidly dissolved on cooling.

If sulphate of magnesia was added to common phosphate of soda, little or no precipitate occurred, but if boiled a gelatinous precipitate fell; this dissolved as the fluid cooled. Under the microscope it was seen to be amorphous (fig. 2). If it was in such excess as not entirely to redissolve on cooling, a few drops of biphosphate immediately made the liquid clear. This, if boiled, gave a plentiful precipitate, and more quickly dissolved on cooling than before. If the liquid was very acid from biphosphate of soda, a slight crystalline precipitate fell, consisting of minute rhombic crystals, similar to those which were seen in the experiment with biphosphate of soda (fig. 5).

If a solution of phosphate of soda was dropped into an excess of sulphate of magnesia, after long standing a crystallization of small needles took place (fig. 6), but the fluid did not become acid to test-paper: nor if dropped into an excess of solution of chloride of magnesium was an acid reaction perceptible.

If to perfectly healthy and strongly acid urine a drop or two of a solution of chloride of calcium is added, no precipitate falls. If the acidity is lessened by any alkali, on boiling a granular precipitate is occasioned. This, when the urine is still acid, is partly or entirely redissolved on cooling; or if alkaline, immediately dissolves in dilute hydrochloric acid without any trace of effervescence.

Between three and five hours after food, at which time the earthy phosphates are always in excess, if healthy acid urine which gives no deposit on boiling has some of its acidity removed by fixed alkalies, or alkaline phosphate, a deposit takes place on boiling, and this is always granular, the fluid becoming more acid than before.

If to such alkaline urine as is passed thick from earthy phosphate a little biphosphate of soda is added, the phosphate redissolves; and if the biphosphate is not added in excess the earthy phosphates can be precipitated by heat, the reaction becoming more acid; but if an excess be added, the fluid remains perfectly clear on boiling.

There is then the closest coincidence between the deposits of earthy phosphates in some states of the urine, and their deposit from solutions of the phosphates of soda; and the same method which is followed for obtaining a precipitate of earthy phosphates dissolved in biphosphate of soda, will give a precipitate from healthy acid urine, and that which hinders precipitation in the one has the same effect on the other.

The deposit of phosphate of magnesia by boiling was supposed by M. Riffault to depend on the formation of a more basic phosphate of magnesia. The same explanation is still more probably the truth regarding the precipitation of the phosphate of lime by boiling, whether from solutions of phosphates of soda or from the urine.

The formation of crystalline earthy phosphates when great excess of earthy phosphate was present while at the same time the biphosphate of soda made the liquid very acid, gives the explanation why crystalline phosphate of lime is so seldom seen in the urine. Still it may occasionally be met with. Crystalline phosphate of magnesia, from its greater solubility, can scarcely appear. The amorphous deposit of phosphate of magnesia when urine is boiled may perhaps be recognised by its far greater solubility than the phosphate of lime as the fluid cools.

In the state of health acid phosphate of soda, mixed probably with common phosphate of soda, holds the earthy phosphates in solution. No precipitate is occasioned by chloride of calcium. If, after the water is passed or before from medicines, or particular food, or state of body, some of the acid phosphate is converted into common phosphate, a precipitate takes place on boiling the acid urine. If this very rapidly dissolves before the fluid is cold, the precipitate contains most probably phosphate of magnesia; if very slowly, it is more likely to be phosphate of lime. If the urine be neutral to test-paper, that is, contains still less biphosphate of soda (the common phosphate being decidedly alkaline to test-paper), then the precipitation is more marked and the re-solution on cooling very much less. If the urine be alkaline, containing only common phosphate, this may be passed clear, and still may contain some phosphate of magnesia and a little phosphate of lime, these being somewhat soluble in common phosphate of soda, and these will be precipitated on boiling.

If the phosphate of lime is from any cause in great excess, it may be deposited as a granular deposit, and never in the crystalline form, unless it be in so great an excess that it is deposited from urine containing very much biphosphate of soda.

The occurrence of the alkaline condition at the particular period of the day which has been observed is well worthy of attention. The whole truth cannot be arrived at without a very lengthened inquiry into the variations in the amount of acids excreted by the kidneys, but partly at least it must depend on the food which has been taken in the morning, that is on the passage of alkaline phosphates, or carbonates, or salts of the vegetable acids through the system. Recent analyses of the ashes of seeds, flesh and blood, do not show any trace of alkaline carbonates, but as these cannot be heated to a red heat with common alkaline phosphates without the loss of carbonic acid, it will be seen how difficult it is to arrive at certainty on this point.

The conclusions from these observations are—

1. That there exist two kinds of alkalescence of the urine; the one long known as ammoniacal, the other not distinctly recognised, arising from fixed alkali. This last appears most frequently in water secreted from two to four hours after breakfast in persons suffering only from indigestion.

2. Water made at this period may be thick when passed from amorphous sediment, or it may be alkaline to test-paper, and still clear; or it may be free from deposit and slightly acid. If either of these last be heated, an amorphous precipitate may fall, which is soluble in dilute hydrochloric acid, or in solution of biphosphate of soda.

3. Healthy urine may at any time be made to give a precipitate of earthy phosphates by heat, even though it be acid, by having a little of its acid reaction removed by any alkali, or by common phosphate of soda, the fluid becoming more acid when boiled.

4. The solution of earthy phosphates in biphosphate of soda, gives also a precipitate on boiling if some of its acid reaction is removed by any alkali. The fluid when boiled becomes more acid to test-paper, indicating the formation of a more basic earthy phosphate.

5. A precisely similar result is obtained when common phosphate of soda, phosphate of lime, and a little biphosphate of soda exist in solution together; and by varying the quantities of each of these substances, the various phenomena which the urine occasionally presents may be produced at will.

6. The time at which the alkalescence of the urine from fixed alkali generally occurs, indicates the existence of some alkaline phosphate or of some carbonated alkali in the food*.

7. The result as regards diagnosis may be thus arranged :—

| Alkalescence of the urine from local causes. | Alkalescence from general causes. |
|---|---|
| Blue paper made markedly red on drying. | Blue litmus paper not made red on drying. |
| Alkalescence constantly present. | Alkalescence variable, usually soon after food. |
| Always contains mucus in excess. | Rarely contains mucus in excess. |
| Prismatic crystals always to be found by microscope. | When first passed generally contains only granular deposit. |

## PLATE V.

Fig. 1. Iridescent pellicles on some alkaline urine.

Fig. 2. Amorphous deposit in alkaline urine.
Deposit on boiling phosphate of soda with chloride of calcium, or with sulphate of magnesia.

Fig. 3. Chloride of calcium with acid phosphate of soda, or with common phosphate of soda ; after long standing.

Fig. 4. Phosphate of soda with little chloride of calcium.
Bone-earth phosphate.

Fig. 5. On boiling phosphate of soda with sulphate of magnesia and little biphosphate of soda.

Fig. 6. Phosphate of soda with sulphate of magnesia; after long standing.

## APPENDIX.

Later experiments have shown that the alkalescence from fixed alkali does not depend on the nature of the food. For example, with a diet of animal food and distilled water, the urine in four hours has been observed to be alkaline. Rather longer after dinner it has also been found to be alkaline. Usually however, after a late dinner, even if the water is secreted alkaline, it becomes mixed in the bladder during sleep with acid water which is afterwards secreted and thus the alkalescence escapes notice.

It seems highly probable that the quantity of acid poured out into the stomach sets free alkali sufficient in some cases to make the urine alkaline; and from facts which have been stated to me, it seems even possible that the same effect on the water may sometimes be produced by the separation of acid by the skin.

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* See Appendix.

# XVI. *On the Gas Voltaic Battery.—Voltaic Action of Phosphorus, Sulphur and Hydrocarbons.*

*By* W. R. Grove, *Esq., M.A., F.R.S., V.P.R.I., Prof. Exp. Phil., London Institution.*

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In a paper which was honoured by publication in the Philosophical Transactions for 1843, I described certain forms of the gas voltaic battery, together with a series of experiments in which different gases were employed as voltaic combinations, and the consequent application of voltaism to eudiometry.

To ensure confidence in the accuracy of the eudiometric experiments, it was essential that the position which I laid down as to the absence of all voltaic action in a combination of oxygen and nitrogen should be rigidly true. I may state with certainty that it is so, but an apparent exception noticed (Exp. 21.) in my last paper obtains during the first few minutes after the circuit is closed, and sometimes for a much longer time. The examination of this temporary action in the first instance, with the view of ascertaining whether it was a specific action of the nitrogen or attributable to adventitious circumstances, led me to the results which I have the honour of laying before the Royal Society in this paper.

Before detailing these results, I will for convenience sake premise that they were all obtained by the form of battery represented in fig. 8 of my last paper (which, with a slight addition to be referred to presently, is again represented at fig. 2, Plate VI.), charged with distilled water slightly acidulated with pure sulphuric acid.

I will also, when alluding to my last paper, to avoid the needless repetition of the word *experiment*, refer to the number of the experiments as though they were paragraphs, and continue those numbers in the paragraphs of this paper.

As the form of battery (fig. 2) by which the interfering action of the atmosphere is entirely prevented was not devised until the greater part of the experiments in my last paper had been completed, I repeated some of them which seemed to require such verification with this battery; to one of these only is it essential that I should now refer. I should likewise mention, that in the experiments to be described the proper reductions for temperature and pressure have been made when necessary; where it was practicable the experiments were examined on days when the temperature and pressure were, as nearly as may be, the same as when they were set by.

(31.) Oxygen and deutoxide of nitrogen, which in the open form of battery gave only a temporary action (9.), when employed in the closed form (fig. 2) gave a continuous current. The following three sets of experiments were continued each for a month in closed circuit, during which time they were constantly tested by the galvanometer and evidenced a continuous voltaic action; at the expiration of the month the results were as follows:—

Experiment 1.—Rise of liquid in tubes of
Oxygen . . . . . . . . =0·32 cubic inch.
Deutoxide of nitrogen. . . . =1·26 cubic inch.
Experiment 2.—In oxygen tubes. . . . . . =0·5 cubic inch.
Deutoxide of nitrogen. . . =2·5 cubic inches.
Experiment 3.—In oxygen tubes. . . . . . =0·2 cubic inch.
Deutoxide of nitrogen . . . =0·75 cubic inch.
Mean result. {In oxygen tubes, rise . . . . =0·34 cubic inch.
In deutoxide tubes, rise . . . =1·5 cubic inch.

The slight excess being undoubtedly due to the greater solubility of the deutoxide, it appears that four volumes of deutoxide of nitrogen are absorbed in the gas battery for one of the associated oxygen, and the result would be a compound of 1 equiv. nitrogen + 3 oxygen, or hyponitrous acid, which is exactly that formed by the slow combination of these two gases in the ordinary chemical way. The difference of amount of action in the three experiments depended on the temperature, the second experiment being made towards the close of last summer, the last experiment during the continuous cold weather of the present spring.

These experiments, coupled with the converse ones with hydrogen and deutoxide of nitrogen (30.), afford very satisfactory instances of the illustration of the law of definite combining volumes by the gas battery, exhibiting in one result, and itself registering that result, the action of equivalent chemical combination, catalysis and voltaism.

(32.) I now pass to the experiments which will form the more immediate subject of this paper. The temporary action to which I have alluded (21.) being greater when nitrogen and oxygen were the gases used, if the nitrogen were obtained by burning phosphorus in atmospheric air, than if procured from other sources, it naturally occurred to me that this action was due either to some phosphorous acid remaining in a state of vapour in the nitrogen, or to a slight portion of the phosphorus itself being held in solution in the nitrogen, as believed by VAUQUELIN and the older experimentalists. If this last supposition were the correct one, it seemed to offer a means of rendering phosphorus, though a non-conductor and insoluble in aqueous liquids, yet a permanent voltaic excitant analogous to the oxidable metals.

(33.) A small piece of phosphorus having been carefully dried, and weighing when dry 9·6 grains, was passed up through the liquid into the large tube of a gas battery by means of a small loop of mica, which kept it separated both from the glass and the platinum; the tube was now charged with pure nitrogen, and the associated tube with pure oxygen, the level of the gases or water-mark being noted by a little slip of paper pasted on the tube; a check experiment of oxygen and nitrogen without phosphorus was charged at the same time; the whole was carefully closed from the atmosphere and set by for twenty-four hours in closed circuit, to get rid of any current from adventitious circumstances; the next day, when tested by the galvanometer and iodide of potassium, a very decided action was apparent in the phosphorus battery, the iodide being decomposed and the galvanometer needle swinging round to 30°, the nitrogen with the phosphorus representing the zinc of an ordinary voltaic combination; the check experiment gave not the least deflection or decomposition. The experiments were suffered to remain in closed circuit for four months, from August 10th to December 14th, 1844, having been frequently tested in the interim, and the galvanometer always evidencing a continuous voltaic action in the phosphorus battery. On the 14th of December, the water in the oxygen tube having by its rise denoted the absorption of a cubic inch of oxygen plus the slight quantity 0·05 cubic inch of oxygen due to solution, as proved by comparison with the second battery, the experiment was examined; the result was as follows:—

Rise of liquid in oxygen tube 1 cubic inch. In nitrogen tube 0.
Original weight of phosphorus 9·6 grains.
Present weight of phosphorus 9·2 grains.

The battery was again charged in a similar manner, and put by on the 19th December 1844; the phosphorus weighed 2·8 grains. This, in consequence of the extremely cold weather which has prevailed almost without intermission from that time to the present period, proceeded much more slowly, and was not examined until May 17th, 1845, when the results were as follows:—

Permanent deflection of galvanometer 8°.
Rise of liquid in oxygen tube 0·35 cubic inch. In nitrogen tube 0.
Weight of phosphorus =2·65.

Taking a mean of these two experiments, which in their relative results approximate more closely than I could have anticipated under the circumstances, we get 0·415 as the proportional weight of phosphorus lost for a cubic inch of oxygen. Now as 24 : 31·4 :: 0·34 : 0·444. The result of these experiments therefore leaves no doubt that phosphorous acid is the product of the voltaic action, as it is of the slow combustion of phosphorus in air. The experiment was repeated with distilled water; the action was at first very trifling, but increased every day, and the water gradually acquired an acid reaction.

No light was apparent in any part of the apparatus when examined in the dark, indeed the action was much too slow to render such an effect probable; though if subsequently by heat or other means I should succeed, as I hope, in producing light, it will be curious to observe in what part of the circuit the luminous effect in the voltaic combustion is perceptible.

A series of ten cells of phosphorus and nitrogen associated with oxygen were charged, and perceptibly decomposed water with platinum electrodes.

The result of the above experiments gives, I believe, the first instance of the employment of a solid, insoluble non-conductor as the excitant of a continuous voltaic current; it proves that the existence of diffused phosphorus in nitrogen, as noticed by the old experimentalists, is not a consequence, as was once believed, of a partial combustion, but of an effusion continuing as long as the previously diffused phosphorus is abstracted, and it gives the very curious result of a true combustion, the combustible and the '*comburant*' being at a distance; phosphorus burned by oxygen which is separated from it by strata both of water and gas, of an indefinite length. This result, arrived at by a progressive series of inductions, scarcely now appears extraordinary, but would have been in all probability listened to with incredulity if simply stated as a fact a few years ago. By the galvanometer we may also ascertain the rate of this very slow and minute chemical action; thus if by an apparatus, as above described, my galvanometer gives a deflection of 8 degrees, I know that the phosphorus is being consumed at the rate of the seven millionth part of a grain per minute.

(34.) The next step was to ascertain whether this action was peculiar to nitrogen or common to other gases; for this purpose, a day or two after the first experiment was set aside, the following were also made, and the dates and results were as follows:—

No. 1. Phosphorus suspended in protoxide of nitrogen associated with oxygen: weight of phosphorus 5·3 grains. Charged August 11th, 1844.

No. 2. Similar experiment, but without phosphorus.

Tested occasionally by galvanometer, the first battery gave invariably a small deflection, but less than in experiment (33.); the second gave no deflection.

Examined the 22nd April, 1845.

No. 1. Water risen in tube of oxygen 0·75 cubic inch.

In protoxide tube 1·7 cubic inch.

No. 2. Water risen in oxygen tube 0·1 cubic inch.

In protoxide tube 1·6 cubic inch.

Phosphorus weighed 5 grains, therefore loss =0·3 grain.

In this experiment the rise of liquid in the tubes containing protoxide was evidently due to the solubility of that gas, as it was very nearly equal in both the batteries, and the second gave not the slightest galvanometric deflection; the result gives 0·65 cubic inch of oxygen consumed by 0·3 grain of phosphorus, bearing nearly the same relative proportions as experiment (33.); the only difference between the action of phosphorus in nitrogen and in protoxide of nitrogen is, that in the former it is more rapid, as proved both by the galvanometric deflection and by the quantity of oxygen absorbed in a given time.

(35.) Charged August 11th, 1844.

No. 1. Phosphorus in carbonic acid gas associated with oxygen; weight of phosphorus 5·9 grains.

No. 2. Same without phosphorus.

Tested by galvanometer, No. 1. always gave a deflection, No. 2. none.

On the 3rd of December the carbonic acid gas in both batteries had been absorbed, and the liquid had reached the extremities of both tubes.

In the oxygen tube of

No. 1, rise of liquid =0·75 cubic inch. In No. 2, 0·05 cubic inch.

Phosphorus weighed 5·6 grains, the proportional weight was therefore 0·3 grain phosphorus to 0·7 cubic inch oxygen.

Here again the proportions came out just as in (33.) and (34.), the intensity of action being intermediate, less than the former and greater than the latter.

(36.) Charged 18th December, 1844.

No. 1. Phosphorus in pure oxygen associated with oxygen, great care being taken to exclude atmospheric air: this arrangement having been kept in closed circuit for twenty-four hours, gave a very feeble deflection of the galvanometer.

Examined 15th February, 1845. The rise of liquid in the tube containing phosphorus was equal to 0·3 cubic inch, in that containing the associated oxygen = 0·05. I find no note of the phosphorus being re-weighed; probably I considered it useless, as the consumption of oxygen in the associated tube was so very trifling, scarcely sufficient to be distinguished from the effect of its solubility.

(37.) Charged 23rd April, 1845.

No. 1. Phosphorus suspended in deutoxide of nitrogen associated with oxygen; weight of phosphorus = 4·3 grains.

No. 2. Same without phosphorus.

Examined May 27th, 1845. Galvanometer gave 25° permanent deflection in No. 1, and 10° in No. 2.

No. 1. Rise of liquid in deutoxide tube =0·7 cubic inch.
Rise of liquid in oxygen tube =0·6 cubic inch.
No. 2. Rise of liquid in deutoxide tube =0·7 cubic inch.
In oxygen tube = 0·2 cubic inch.

Weight of phosphorus 4·17 grains.

Consequently had lost 0·13 grain for 0·4 cubic inch of oxygen.

In this and all the preceding experiments the residual gases were unchanged in quality, and in this experiment it appears that the action of the deutoxide of nitrogen and the oxygen was perfectly unaffected by the phosphorus, the consumption of deutoxide of nitrogen being exactly the same in both batteries. In another experiment, which I did not record on account of a minute bubble of air having entered the tubes containing the deutoxide, the phosphorus appeared to have exercised a retarding influence on the voltaic combination of deutoxide of nitrogen and oxygen; this I attributed to a slight deposit of phosphorous acid upon the platinum, by which its catalytic power was deteriorated.

(38.) It thus appears that the effect we have been examining, of the diffusion of phosphorus in gas, is not due to any peculiarity of nitrogen, and is not peculiar to any particular gas, as once believed; but being in all probability common to all gases which do not exercise a specific action on the phosphorus, it may be more properly called a volatilization of phosphorus at ordinary temperatures than a solubility in gas; the ordinary slow combustion of phosphorus in air is, in fact, a combustion of its vapour. I incline to think that the inferiority of its vaporization in pure oxygen is due to a protecting film being formed, and that the phenomenon is in some respects analogous to the inactivity of iron in nitric acid.

(39.) Phosphorus in nitrogen was associated with hydrogen in the gas battery to ascertain their voltaic relation; the hydrogen was positive to the phosphorus, *i. e.* represented the zinc of an ordinary voltaic combination.

(40.) To realize the curious novelty of two non-conducting solids forming the elements of a voltaic battery, and producing a continuous current, phosphorus suspended in nitrogen in one tube of a gas battery was associated with iodine in nitrogen in the other; a very decided current was the result, which continued for months, the nitrogen remaining unaltered in volume, but the liquid becoming gradually tinged by the excess of iodine vapour. The following is the result of the experiment:—

| Charged January 1, 1845. | | Examined May 17, 1845. | |
|---|---|---|---|
| Weight of iodine . . | =5·9 grains. | Weight of iodine . . | =4·6 grains. |
| Weight of phosphorus. | =6·4 grains. | Weight of phosphorus. | =6·28 grains. |

The phosphorus has consequently lost 0·12 grain, the iodine 1·3. Assuming that the phosphorus consumed 3 equivalents of oxygen, as in experiments (33.), (34.), (35.), (37.), we should have 3 equivalents of hydrogen eliminated, and consequently 3 of iodine consumed, or

$$31{\cdot}4 : 126{\cdot}6 :: 0{\cdot}12 : 0{\cdot}48$$

$$0{\cdot}48 \times 3 = 1{\cdot}44.$$

The result is tolerably near, but from the iodine vapour in solution an excess and not a deficit in the consumption of this was to have been expected.

(41.) It was necessary for my own satisfaction to make a great number of other experiments for the purpose of checking and eliminating any adventitious results which might possibly interfere with the actual voltaic action of the gas battery, such as placing phosphorus in single tubes containing the different gases, but with platinum foil and without associated tubes, others without the platinum foil or associated tubes; but as these had no influence on the results, and were merely used as tests for my own satisfaction, it would be useless and tedious to detail them.

(42.) Having examined the action of phosphorus in the gas battery under these various circumstances, my next step was to ascertain if any other substance produced a similar effect. Sulphur, the nearest analogue of phosphorus, was the body which naturally presented itself, but from its different characteristics required a different mode of manipulation. The following was adopted. Into a little capsule of glass, having a long solid leg (see fig. 1), was placed a small piece of solid sulphur; this was held in the large aperture of a gas battery cell, while the tube was passed carefully over it; the platinum in this tube was connected with the zinc of a single cell of the nitric acid battery, while an anode of platinum was placed in the liquid through the central aperture; by this means all the oxygen of the atmospheric air was exhausted, and the surplus hydrogen was in turn taken away by connection with the associated tube charged with oxygen; the same effect might have been more slowly produced by the process described (29.). The sulphur was now in an atmosphere of pure nitrogen, and this could have been effected in no other way that I am aware of without wetting or forming some deposit on the sulphur. Having connected it in closed circuit with the oxygen tube for twenty-four hours, the galvanometer gave no deflection. A small hoop of iron with a handle was now heated and passed over the tube containing sulphur and nitrogen, the wires being connected with the galvanometer (see fig. 2). The result was very striking: I had directed my assistant to watch the galvanometer while I attended to the manipulation. At the same instant he exclaimed that the galvanometer was deflected, and I that the sulphur was melting; the galvanometer continued deflected during the whole time that the sulphur remained fused, and indeed some time afterwards, until all the sulphur vapour diffused in the nitrogen had become exhausted. The sulphur represented the zinc of an ordinary voltaic combination. It was of course impracticable in this case to ascertain the equivalent consumption. This experiment very strikingly exhibits the analogy of sulphur with phosphorus, and proves that the instant sulphur is fused it becomes a volatile body, as phosphorus is when solid; the suddenness of its action, coupled with the insoluble character of sulphur, leads to the conclusion that solution in the electrolyte is not a necessary antecedent to voltaic action in the gas battery. Indeed this might have been deduced from the experiments with phosphorus, as its vapour must have been nearly, if not absolutely insoluble in the electrolyte, or the equivalent results would not have come out so accurately; possibly solution and electrolysis are in these cases synchronous.

(43.) I was now led to try in the gas battery other substances differing from phosphorus and sulphur, but possessing characters which had hitherto prevented their being used as voltaic excitants; as, if my view of the volatility of phosphorus and sulphur were correct, other volatile bodies ought to act similarly. Camphor was the first substance I experimented on. A piece of camphor weighing 12·9 grains, was placed in a similar manner to the phosphorus (33.) in nitrogen, and associated with oxygen; tested by the galvanometer it gave a feeble deflection, which, however, was continuous; it was allowed to remain four months in closed circuit; at the expiration of that time the liquid had risen in the oxygen tube 0·3 cubic inch; the nitrogen in which the camphor was suspended had increased in volume 0·15 of a cubic inch. The camphor weighed 11·4 grains, but some minute crystals of it were observed at the top of the tube, so that the loss of weight was greater than that due to voltaic action.

(44.) The smallness of the quantity of the gas which had been added to the nitrogen, precluded an accurate analysis of it; enough was ascertained, however, to lead me to believe that it was hydrocarbonous, and it then became my aim to produce it in greater quantities. I attached a piece of camphor to a platinum wire, and to the same wire I also attached a piece of sponge platinum; I passed these up into a tube of nitrogen over distilled water, and at the expiration of three months the gas had increased 0·1 cubic inch; this proved that the camphor vapour was decomposable by the catalytic action of platinum at ordinary temperatures, and that the effect in the nitrogen cell of the battery was not due to its voltaic association; but the experiment did not give me a sufficient quantity of the gas for analysis.

(45.) I therefore had recourse to the apparatus, fig. 3. *a* is an inverted cylindrical test-glass; *b* a platinum capsule with a pin-hole in the bottom for drainage, standing on an ivory pedestal; *c*, *c* two very stout platinum wires; *d* a coil of fine platinum wire. Into the capsule *b* was placed the camphor, the glass *a* filled with distilled water was inverted over it and charged with pure nitrogen, to a level marked somewhere below the capsule; the wires *w w'* are now connected with a voltaic battery of sufficient power fully to ignite the wire *d*.

(46.) After the wire was ignited the volume of the gas gradually increased; when the original volume was doubled, the gas was examined. It had a strong disagreeable odour, very similar to that of coal-gas; it burned with a blue flame, slightly tinged with yellow: placed in an eudiometer, such as I formerly described*, and mixed with hydrogen, it underwent no alteration. Two volumes of it, mixed with one volume of oxygen, contracted one-sixth of the whole volume, and subsequently agitated with lime-water, contracted two-sixths more, lining the tube with a crust of carbonate of lime. The residual gas was nitrogen. It was thus clear that the vapour of camphor was decomposed by the ignited wire into carburetted hydrogen and carbonic oxide, and the analogy is too direct to leave any doubt that these gases were also formed in experiments (43.) and (44.) by the influence of the platinum foil and spongy platinum.

The apparatus (fig. 4) offers a most convenient means of decomposing volatile hydrocarbons, and possibly other substances.

(47.) Portions of oil of Turpentine and of Cassia were now placed in capsules (fig. 1), weighed and exposed each to an atmosphere of nitrogen in the large tube of a gas battery, by the same means as described (42.); they gave a very decided deflection (the nitrogen representing zinc). This deflection continues, and the liquid is slowly rising in the oxygen tubes, but the rise is too slight at the time of my writing this paper to derive any useful result from examining the present weight†.

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* Philosophical Magazine, August 1841, p. 99, and Philosophical Transactions, 1843, p. 105.

† Dec. 1845.—The rise of liquid has been slow but continuous, and the galvanometer feebly deflected. In the Turpentine experiment the rise is =0·7 cubic inch, in the Cassia 0·5; the weights, however, from the irregularity of absorption and evaporation, give no data as to the equivalent consumption; thus the Turpentine has lost 0·7 grain, the Cassia gained 0·05 grain.

(48.) Alcohol and ether were tried in a similar manner, and produced notable voltaic effects; alcohol the most powerful probably, on account of its greater solubility in water.

(49.) The rationale of the action in experiments (43.) and (47.) is curious. It seems that the platinum in the nitrogen tube first decomposes the vapour of the hydrocarbons*, and then the same platinum, with its associated plate, recombines the separated constituents with oxygen. In experiment (43.) the decomposition takes place more quickly than the recomposition, as indeed would be expected from the absence of the resistance of the electrolyte in the former case, and hence the increase of gas in the nitrogen tube.

(50.) The analogy of the action of the above volatile substances strengthens the position advanced (38.), that solid phosphorus should be regarded as volatile at ordinary temperatures, and sulphur when fused; the whole of these experiments also serve to introduce the galvanometer as a new and delicate test, and in some cases a measurer of volatilization.

(51.) As the gas battery was shown in the former paper, which I had the honour to communicate to the Society, to give us the power of introducing gases which had been previously untried as voltaic excitants, and to ascertain their electro-chemical relations, it has, by the means detailed in this paper, opened a field for ascertaining the voltaic relations and quantitative electro-chemical combinations of solid and liquid substances, which from their physical characteristics had not hitherto been recognised in lists of the voltaic relations of different substances, and consequently formed to a certain extent a blank in the chemical theory (may we not now call it law?) of the voltaic pile. These results, coupled with the previously-arranged tables of electro-chemical relations, and with the great improvements in apparatus for measuring these relations recently made by Mr. Wheatstone and others, offer every promise of the ultimate establishment of accurate measures of affinity. I give the following tables as an approximative list, without attempting to give the degrees of intensity, which can only be filled up by a careful series of researches exclusively devoted to this object.

(52.) Chlorine.
Bromine.
Iodine.
Peroxides.
Oxygen.
Deutoxide of nitrogen.
Carbonic acid.
Nitrogen.
Metals which do not decompose water under ordinary circumstances.

Camphor.
Essential oils.
Olefiant gas.
Ether.
Alcohol.
Sulphur.
Phosphorus.
Carbonic oxide.
Hydrogen.
Metals which decompose water.

---

* I use this word here and in the title to avoid periphrasis; it is not quite correct as applied to some of these bodies.

Though carbonic acid and nitrogen appear to be neutral, and consequently might be bracketed with the metals which do not decompose water, as forming the nodal point or zero of the table, yet, in consequence of the peculiar action exercised by them, and detailed (29.) and (30.), I have placed them above the metals*.

(53.) The results embodied in my present and my former paper, I think sufficiently indicate the field of research opened by the gas battery, a field which may of course be indefinitely extended. I have never thought of the gas battery as a practical means of generating voltaic power, though in consequence of my earlier researches, which terminated in the nitric acid battery, having had this object in view, I have been deemed by some to have proposed the gas battery for the same purpose; there is, however, a form of gas battery which I may here describe, which, where continuous intensity or electromotive force is required, but the quantity of electricity is altogether unimportant, appears to me to offer some advantages over any form of battery hitherto constructed, and which, independently of any practical result, is, from circumstances peculiar to the gas battery, not without interest. It is shown at figs. 4 and 5. A A′ is a long glass tube, with a series of legs or glass tubes attached to and opening into it; the lower extremities of these are open, and the main tube or channel A A′ terminates at the extremity A in a glass stopper, and at A′ opens out into a funnel, as shown in the figure. Into a series of glasses B B′ are cemented platinum wires having attached to them strips of platinized platinum foil, two to each glass, the one being four inches long and half an inch wide, the other 1½ inch long by one inch wide; the former set are placed lower than the latter, so that when the glasses are filled with liquid the former set shall be just covered, and the latter bisected by the water-mark; the last glass B has no platinum. These platinum strips are connected metallically by external wires, the narrow platinum of one cell with the wide one of the next, and so on in series. The glasses having been filled to the top of the narrow platinum with acidulated water, let a piece of zinc be placed on a pedestal in the vessel B, and the stopper being out of the extremity A, the apparatus A A′ lowered into the glasses, the tubular legs covering each one of the narrow platinum plates. The tubes will of course be full of water, and the main channel full of atmospheric air; this will gradually be displaced by the hydrogen ascending from the zinc, which hydrogen, in consequence of the curve at A, will retain its position. When it is judged that the greater portion of air has been expelled, the stopper at A, covered with a little grease, is to be inserted; the hydrogen now will rapidly descend in all the tubes until the zinc is laid bare, and then remain stationary.

We have now a gas battery, the terminal wires of which will give the usual voltaic effects, the atmospheric air supplying an inexhaustible source of oxygen, and the hydrogen being renewed as required by the liquid rising to touch the zinc; by supplying a fresh piece of zinc when necessary, it thus becomes a self-charging battery, which will give a continuous current; no new plates are ever needed, the electrolyte is never saturated, and requires no renewal except the trifling loss from evaporation, which indeed is lessened, if the battery be in action, by the newly composed water. There is an aperture in the pedestal with a moveable slide, through which the vessel B′ can be removed, when necessary, to replace the zinc, and the remaining part of the apparatus is never disturbed. This battery would form an elegant substitute for the water battery; it would much exceed in intensity a similar number of series of that apparatus; it would be applicable to experiments of slow crystallization and possibly to the telegraph. Its construction is difficult and makes its prime cost expensive, but after that it is the most durable, the most easily charged, and the most free from local action of any known form. I have had one of ten cells constructed, shown at fig. 5, which succeeds perfectly, giving sparks, decomposing water, &c., and is ever ready for use. Any number of such sets might be united by adapter-tubes; or indeed it would be much more economical, and reduce to a minimum the damage from breakage, to have the main channels A A′ made of varnished wood or porcelain, with apertures into which separate glass tubes might be cemented.

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* I have been lately much struck with the difficulty of reconciling the theory of GROTTHUS with many of the combinations in the gas battery, and have stated this difficulty in the Philosophical Magazine for Nov. 1845.

*London Institution, May* 30, 1845.

## XVII. *On the Compounds of Tin and Iodine.* *By* Thomas H. Henry, *Esq.* *Communicated by* R. Phillips, *Esq., F.R.S.*

Received March 31,—Read June 19, 1845.

In a paper by Sir H. Davy, published in the Philosophical Transactions, 1814, he describes the compound of tin and iodine procured by heating these bodies together, out of the contact of air, as of a deep orange colour, fusible at a moderate heat, and volatile at a higher temperature.

The compound obtained by Gay-Lussac, by gently heating tin with twice its weight of iodine, and more recently by Rammelsberg, by the same method*, is described by them as a reddish-brown, transparent substance, yielding a powder of a dirty orange-yellow colour, and easily fusible.

A compound of tin and iodine was procured by Boullay†, by precipitating a solution of protochloride of tin with iodide of potassium, in slight excess.

The combinations procured by these methods have been considered to be identical in composition, although the compound procured both by Gay-Lussac and by Rammelsberg is stated by them to be decomposed by water, while the salt of Boullay is described by him as soluble in water without decomposition.

It will be seen, I think, from the following experiments, that the substance procured by heating tin with twice its weight of iodine, is a mixture of two salts, differing in composition, one of which is soluble in water to a slight extent, without suffering decomposition, while the other is immediately decomposed on bringing it in contact with water, the former being the real protiodide described by Boullay, and the latter a biniodide, a salt which has not yet, to my knowledge at least, been described, but which must have been the compound mentioned by Sir H. Davy, as it is of a brilliant orange colour, and sublimes at a temperature of 356° Fahr., while the protiodide, I find, may be heated to redness, out of the contact of air, without subliming.

100 grs. of tin, in a state of minute division, were mixed with 220 grs. of iodine, the mixture placed in a porcelain crucible well-covered, and sufficient heat being applied to fuse the iodine, violent action immediately took place, accompanied by the evolution of much heat and the sublimation of a portion of the iodine; when the action had ceased and the crucible had become cool, a brown transparent crystalline mass, weighing 310 grs., was removed from it; 10 grs. of iodine had been sublimed, therefore, by the heat evolved during the combination; upon breaking this mass, however, a button of metallic tin, weighing 45 grs., was found inclosed in it. This

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* Gmelin, Handbuch, vol. iii.

† Annales de Chimie, xxxiv. 372.

substance could not be the neutral compound, for the 210 grs. of iodine would require 98 grs. of tin to form the protiodide instead of only 55 grs.

The mass was therefore heated again in a Florence flask well-corked, with 45 grs. of tin in very fine powder, to replace the button removed from it, in order to ascertain whether the neutral compound could be procured by digesting this substance with the metal in a state more favourable to combination. The mass readily fused without any further action on the tin; but an orange-red sublimate was formed, condensing on the sides of the flask in brilliant acicular crystals. As the mass in the flask diminished in quantity, it became less fusible, until at length it required a degree of heat little short of dull redness to produce that effect, and then it ceased to give off vapour. The flask was now allowed to cool; when cold, it was cut, and the fused residue removed, which was found to weigh 86·5 grs. after the separation of 37·5 grs. of tin still uncombined.

This substance was of a deep red colour and crystalline texture, affording a powder of a bright red colour similar to that of minium; 50 parts of it were treated with strong nitric acid, which acted violently upon it, expelling iodine and leaving peroxide of tin, which weighed after ignition 22·1 parts = 17·38 metallic tin = 34·76 per cent.; a compound of one equivalent of tin = 59, and one of iodine = 126, would give 31·89 per cent. This excess in the quantity of tin arose from the heat employed in separating the two compounds, producing a portion of oxide by the decomposition of the protosalt, as will be seen further on. To ascertain the composition of the sublimate, 50 parts of it were decomposed by nitric acid, and gave 12·2 parts of peroxide = 9·597 metal = 19·19 per cent.

100 parts, treated with a solution of pure carbonate of potash in slight excess, were decomposed, carbonic acid being evolved and peroxide of tin precipitated; the iodide of potassium produced was separated by alcohol, and after dilution with water, was treated with nitrate of silver; the precipitate dried and fused weighed 148·5 = 79·99 iodine. This gives

| | Theory. | | Experiment. |
|---|---|---|---|
| 2 Iodine | =252 | 81 | 79·99 |
| 1 Tin . | = 59 | 19 | 19·19 |
| | 311 | 100 | 99·18 |

It was therefore a biniodide.

In the next experiment, I took one atom of each substance, viz. 59 grs. of tin and 126 grs. of iodine. The action was violent as before; there were 16 grs. of tin uncombined, and after the sublimation of the biniodide, the fused protosalt weighed 66 grs.; this was exposed to the air as little as possible during the process of sublimation, which being performed in a retort, less oxide was formed in consequence.

50 parts gave 21·1 peroxide of tin = 33·2 per cent. metal. In order to ascertain the action of heat upon the protiodide of tin, I prepared some by precipitating a warm concentrated solution of recently prepared protochloride of tin, by a strong solution of iodide of potassium, in slight excess; the salt formed on cooling in beau-

tiful acicular crystals, which, after being washed with a little water, lost their lustre by drying at a very gentle heat.

50 parts gave 20·7 parts peroxide =32·36 per cent. tin; 10 grs. of this were heated in a small tube, tightly corked, at first gently, and afterwards to complete fusion; a little water condensed on the upper part of the tube with a minute portion of biniodide. When cold the tube was cut, the fused mass removed, and found to have lost 1·5 gr.; it was slightly oxidized on the surface, and perfectly resembled the protiodide procured in the former experiments.

25·3 grs. of the same salt were heated to from 380° to 400° in an open porcelain crucible, a sublimate was produced, which was received in a paper cone, so placed on the crucible as not to prevent the access of air; when no more vapour was given off, the crucible was cooled and weighed; the residue was found to weigh 6·04 grs.; it was ignited, and then weighed 5·91 grs., and was peroxide of tin. The sublimate, which was in small brilliant orange-red crystals, was biniodide of tin; for 4·60 grs., decomposed with nitric acid and ignited, gave 1·115 peroxide = 19·06 per cent. of metal.

Now, supposing that two atoms of protiodide of tin had been decomposed, giving rise to one atom of periodide, and one atom of peroxide of tin, 25·3 grs. of protiodide should have left 5·13 grs. of peroxide, which is sufficiently near the quantity obtained to determine the nature of the decomposition. **Berzelius** states that the protofluoride of tin is converted, by the action of the atmosphere, into $SnF^2$, $SnO^2$; a decomposition exactly analogous to that above described.

I have not succeeded in obtaining a combination of tin and iodine corresponding to the sesquioxide, although **Boullay** conjectured that some yellow crystals, which he obtained on adding to a solution of protochloride of tin a solution of iodide of potassium, in which an additional half-atom was dissolved, were sesqui-iodide; the crystals I obtained by this method were found to be pure protiodide.

On adding iodine to a solution of protochloride of tin, this salt suffers a remarkable decomposition; if its solution be concentrated, an iodide of tin is precipitated, and a combination of chloride and iodide of the metal, in definite proportions, remains dissolved in the solution. If the iodine be added in excess, so that the solution acquires a brown colour, it yields crystals of biniodide on evaporation; if, on the other hand, the protochloride be in excess, a portion of the protiodide is precipitated, and the remainder unites with protochloride of tin, in the proportion of one equivalent of each substance, and it remains dissolved in the solution of protochloride, but may be separated by evaporation in the form of delicate acicular crystals of a silky lustre, and straw-yellow colour.

On adding iodine to an equal weight of protochloride of tin, dissolved in a small quantity of water, I obtained some minute red crystals, which yielded on analysis

|  | Per cent. |
|---|---|
| Iodine . . . . . . | 79·30 |
| Tin . . . . . . . . | 19·98 |
|  | 99·28 |

it was the biniodide therefore; with 380 grs. of the protochloride of tin and 150 grs. of iodine, a precipitate was obtained, which was found to yield—

| | Per cent. |
|---|---|
| Iodine . . . . . | 67·78 |
| Tin . . . . . . . | 31·67 |
| | 99·45 |

it was therefore protiodide of tin.

The solution remaining after the precipitation of the protiodide was evaporated at a gentle heat, until sufficiently concentrated, and allowed to cool; some crystals were thus obtained which were freed as much as possible from the mother-liquor, by pressure in bibulous paper, but on attempting to purify them for analysis by redissolving them in water, they were immediately decomposed, giving a scarlet crystalline precipitate of protiodide of tin, while chloride of tin remained in solution; they were therefore pressed as dry as possible in bibulous paper, and afterwards retained *in vacuo* over sulphuric acid for some hours.

10 grs. were then treated with a solution of pure carbonate of potash, evaporated to dryness, redissolved in cold water and separated from the protoxide of tin by filtration; the solution acidulated with nitric acid, and the iodine precipitated by nitrate of palladium while hot, the precipitate washed, dried, and ignited, left 1·94 gr. of metallic palladium =4·586 grs. iodine. The chlorine was afterwards precipitated by nitrate of silver; the precipitate, washed, dried, and fused, weighed 5·22 grs.; upon dissolving the chloride of silver in ammonia 0·1 gr. of metallic palladium was separated, which had subsided with the chloride of silver as a subsalt; this leaves 5·12 for the true weight of the chloride of silver =1·263 chlorine; 5 grs. decomposed with nitric acid in excess, evaporated to dryness and ignited, gave 2·68 grs. peroxide of tin =2·108 of metallic tin.

This gives in 100 parts—

| | Theory. | | Per cent. | Experiment. |
|---|---|---|---|---|
| One atom chlorine = | 35·4 | or | 12·67 | 12·63 |
| One atom iodine = | 126 | or | 45·10 | 45·86 |
| Two atoms tin . . = | 118 | or | 42·23 | 42·16 |
| | 279·4 | | 100·00 | 100·65 |

It is therefore a compound of one atom of protochloride of tin, and one atom of protiodide of tin.

The excess in the quantity of iodine in the above analysis, is probably owing to the tendency of the protonitrate of palladium to subside as a basic salt in company with precipitates, which is a great objection to its employment in analysis.

As the protochloride of tin is stated by GMELIN[*], on the authority of BERZELIUS, to contain one atom of water of crystallization, while the late Dr. TURNER, in the last edition of his Elements, published during his life[†], states that it contains three atoms of water of crystallization, and several works of character do not give the composition of the crystallized salt at all, it became necessary to analyse the salt used in the above experiments; it was obtained by digesting strong hydrochloric acid with tin in excess at a moderate heat, and when a tolerably concentrated solution was obtained, decanting it and setting it aside to crystallize; the strongly acid mother-liquor was again digested with the tin and took up a fresh portion (it appears impossible to saturate hydrochloric acid with tin at once). The salt was in small prismatic crystals and dissolved in water, after drying on blotting-paper, forming a perfectly clear solution, and producing a great degree of cold; 700 grs. dissolved in 3 oz. of water reduced the temperature from 58° to 27° Fahr.

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[*] Handbuch, vol. iii.

[†] Edit. v. p. 550.

The crystals were coarsely powdered and pressed as dry as possible in bibulous paper; 25 grs. were dissolved in water acidulated by sulphuric acid, and the tin precipitated by sulphuretted hydrogen, the protosulphuret washed and dried, weighed 17·23 grs.; 16·2 of these were ignited in a porcelain crucible, and the ignition, repeated with a little carbonate of ammonia, gave 15·6 grs. of peroxide; this corresponds to 16·59 on the total quantity of sulphuret, which is equivalent to 13·09 of metal.

The excess of sulphuretted hydrogen was removed by a little sulphate of copper, and the chlorine, precipitated by nitrate of silver, gave 30·94 grs. of fused chloride of silver =7·72 chlorine.

To determine the water, 23·58 grains were retained *in vacuo* over sulphuric acid for twenty-four hours, and were found to have lost 3·87 grains = 16·41 per cent.; we have therefore—

| | Experiment. | Theory. | Atom. | |
|---|---|---|---|---|
| Chlorine . . . | 30·88 | 31·50 | 1 | 35·4 |
| Tin . . . . | 52·36 | 52·49 | 1 | 59 |
| Water. . . . | 16·41 | 16·01 | 2 | 18 |
| | 99·65 | 100·00 | | 112·4 |

The following table contains the principal analytical results of this communication:—

| | |
|---|---|
| Protiodide of tin . . . | SnI, solid and fixed, sparingly soluble. |
| Periodide of tin . . . | $SnI_2$, solid, volatile, decomposed by water. |
| Chloriodide of tin . . . | SnCl, SnI, solid, fixed, decomposed by water. |

*March* 28, 1845.

of water of crystallization, and several works of chemistry do not give the composition of the crystallized salt at all, it became necessary to analyse the salt used in the above experiments; it was obtained by digesting strong hydriodic acid with tin in excess at a moderate heat, and when a tolerably concentrated solution was obtained, decanting it and setting it aside to crystallize. The strongly acid mother-liquor was again digested with the tin and took up a fresh portion (it appears impossible to saturate hydriodic acid with tin at once). The salt was in small prismatic crystals and dissolved in water after drying on blotting paper, forming a perfectly clear solution, and producing a great degree of cold; [illegible] dissolved in [illegible] of water reduced the temperature from [illegible] to [illegible] Fahr.

The crystals were carefully pressed and dried as far as possible in filtering paper; 25 grs. were dissolved in water acidulated by sulphuric acid and the tin precipitated by sulphuretted hydrogen; the proto-sulphuret washed and dried, weighed [illegible] grs.; 10·2 of these were ignited in a porcelain crucible, and the residue, repeated with a little carbonate of ammonia, gave [illegible] grs. of peroxide; this corresponds to [illegible] on the total quantity of sulphuret, which is equivalent to [illegible] of metallic tin.

The excess of sulphuretted hydrogen was removed by a gentle heat, and the iodine precipitated by nitrate of silver gave [illegible] grs. of fused iodide of silver [illegible] iodine.

To determine the water, [illegible] grains were exposed in vacuo over sulphuric acid for twenty-four hours, and were found to have lost [illegible] grains [illegible] per cent. of water; the composition of the crystallized salt is therefore,—

| | Experiment. | Theory. | Atom. | |
|---|---|---|---|---|
| Iodine | [illegible] | [illegible] | 1 | [illegible] |
| Tin | [illegible] | [illegible] | 1 | [illegible] |
| Water | [illegible] | [illegible] | 2 | [illegible] |
| | [illegible] | 100·00 | | [illegible] |

The following table contains the principal analytical results of this communication:—

Protoxide of tin [illegible] salt, soluble and fixed [illegible].
Periodide of tin [illegible] salt, solid, volatile, decomposed by water.
[illegible] of tin [illegible] salt, solid, fixed, decomposed by water.

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| 1816. Feb. 8. | | Bland, Michael, Esq., F.S.A. F.G.S. *St. Leonard's, Hastings.* |
| 1821. Apr. 12. | | Bland, Rev. Miles, D.D. F.S.A. F.R.A.S. M.R.S.L. *Lilley Rectory, near Luton.* |
| 1841. June 10. | † | Blore, Edward, Esq. 4 *Manchester-square.* |
| 1837. May 11. | | Bosse, Henry, M.D. F.G.S. *Claverhouse, near Dundee.* |
| 1840. Mar. 5. | † | Boileau, John Theophilus, Esq. Major E.I.C.S. *India.* |
| 1843. June 1. | | Boileau, Sir John, Bart. 20 *Upper Brook-street; and Ketteringham Hall, Norfolk.* |
| 1840. June 18. | † | Bonner, Col. John George, E.I.C.S. 11 *A, Great Cumberland-street, Hyde-park.* |
| 1834. Apr. 10. | † | Booth, Sir Felix, Bart. 43 *Portland-place; and Hendon, Middlesex.* |
| 1835. June 4. | † | Borrer, William, Esq., F.L.S. *Henfield, Sussex.* |
| 1818. Apr. 2. | | Bostock, John, M.D. F.L.S. F.G.S. F.R.A.S. 22 *Upper Bedford-place.* |
| 1829. June 4. | | Bosworth, Rev. Joseph, LL.D. F.S.A. M.R.S.L. Soc. Reg. Antiq. Septen. Hafn. Corresp. Socc. Reg. Sc. Norv., Dronth., et Gotho. Socius. 9 *Southampton-street, Bloomsbury; and Etwell, Uttoxeter, Staffordshire.* |
| 1839. Jan. 17. | | Botfield, Beriah, Esq., M.P. F.S.A. F.R.A.S. F.G.S. F.L.S. *Norton-hall, Northamptonshire.* |
| 1814. May 5. | | Boughton, Sir William Edward Rouse, Bart. *Downton-hall, Ludlow.* |
| 1842. Nov. 17. | | Bowerbank, James Scott, Esq., F.G.S. 45 *Park-street, Islington.* |
| 1841. Apr. 22. | | Bowman, William, Esq. 14 *Golden-square.* |
| 1814. June 23. | | Boyle, Hon. Sir Courtenay, Knt. 24 *Upper Berkeley-street; and Hampton-court Palace.* |
| 1809. Apr. 13. | | Brande, William Thomas, Esq., Professor of Chemistry in the Royal Institution, F.R.S.E. *Royal Mint, Tower-hill.* |
| 1821. Mar. 8. | | Brandreth, Thomas Shaw, Esq. *University-club.* |
| 1841. Jan. 21. | † | Brandreth, Henry Rowland, Esq., Capt. R.E. *Somerset-house.* |
| 1834. June 5. | † | Breadalbane, John Campbell, Marquis of. 21 *Park-lane; and Taymouth-castle, Aberfeldie.* |
| 1815. May 4. | | Brewster, Sir David, K.H. LL.D. F.R.S.E. Hon. M.R.I.A. F.G.S. F.R.A.S. Instit. Reg. Sc. Paris. Corresp.—Soc. Reg. Sc. Gotting. Socius. Principal of St. Leonard's College. *St. Andrew's.* |
| 1821. Mar. 15. | | Bridgman, William, Esq., F.S.A. F.L.S. *Frogmore, Gloucester.* |
| 1838. Nov. 22. | † | Briggs, Major-General John, E.I.C.S. M.R.A.S. F.G.S. 2 *St. James's-square, Cheltenham.* |
| 1821. Mar. 8. | | Bright, Richard, M.D. Coll. Reg. Med. Socius, F.G.S. Soc. Reg. Med. Hafn. Socius.—Acad. Sc. Sien., Socc. Erud. Hung., et Medico-Chir. Berolin. Corresp. 11 *Saville-row.* |
| 1810. May 10. | | Brisbane, Lieut.-General Sir Thomas Macdougall, Bart. K.C.B. G.C.H. D.C.L. President of the Royal Society of Edinburgh, Hon. M.R.I.A. F.R.A.S. F.L.S. Instit. Reg. Sc. Paris. Corresp. *Makerstown, Kelso.* |
| 1805. May 23. | | Bristol, Frederick William, Marquis of. 6 *St. James's-square; and Ickworth-park, Bury St. Edmunds.* |
| 1834. Dec. 18. | † | Brockedon, William, Esq. 29 *Devonshire-street, Queen's-square.* |

| Date of Election. | |
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| 1828. Feb. 14. | Broderip, William John, Esq., B.A. F.L.S. F.G.S. 2 *Raymond's-buildings, Gray's-inn.* |
| 1810. Feb. 15. | * Brodie, Sir Benjamin Collins, Bart. Serjeant Surgeon to the Queen. Inst. Reg. Paris. Corresp. 14 *Saville-row.* |
| 1817. Mar. 13. | Bromhead, Sir Edward Ffrench, Bart. M.A. F.R.S.E. F.R.A.S. *Thurlby, Lincolnshire.* |
| 1823. May 29. | Brooke, Sir Arthur Brooke de Capell, Bart. M.A. F.L.S. F.G.S. *Okeley, Northamptonshire.* |
| 1819. Apr. 22. | Brooke, Henry James, Esq., F.L.S. F.G.S. *Clapham-rise.* |
| 1803. Mar. 3. | Brougham and Vaux, Henry, Lord, M.A. Instit. Reg. Sc. Paris. Socius. 4 *Grafton-street; and Brougham-hall, Penrith.* |
| 1842. Feb. 17. | † Broughton, Robert Edwards, Esq. 1 *Melcombe-place.* |
| 1811. Dec. 12. | Brown, Robert, Esq., D.C.L. Hon. Mem. R.S.E., R.I.A., Med.-Chirurg. S., and C.P.S. V.P.L.S. Instit. Reg. (Acad. Scient.) Paris. Socius.—Acadd. Reg. Scient. Berol., et Taurin., Imp. Sc. Petrop., Reg. Sc. Holm., Monach., Neapol., Bruxell. et Bonon., Instit. Reg. Sc. Amstelod., Socc. Reg. Sc. Hafn., et Upsal., Acad. Cæs. Nat. Cur., Socc. Sc. Harlem., Trajectin., Phys. et Hist. Nat. Genev., Imp. Hist. Nat. Mosc., Nat. Scrutat. Berolin., Wetter., Phil. Nov.-Ebor., Med. et Phys. Bengal., et Med. Holm. Socius. 17 *Dean-street, Soho.* |
| 1838. May 8. | Brownlow, John, Earl, D.C.L. F.S.A. F.L.S. F.G.S. M.R.A.S. 12 *Belgrave-square; and Belton-house, Grantham.* |
| 1829. Mar. 18. | Bruce, Right Hon. Sir James Lewis Knight, Knt. F.S.A. Vice-Chancellor. *Roehampton Priory.* |
| 1830. June 10. | Brunel, Isambard Kingdom, Esq. 18 *Duke-street, Westminster.* |
| 1814. Mar. 24. | Brunel, Sir Mark Isambard, Knt., Instit. Reg. Sc. Paris., et Acad. Reg. Sc. Monach., Corresp. |
| 1833. June 20. | Buccleuch, Walter Francis, Duke of, K.T. D.C.L. F.L.S. *Whitehall-gardens; and Dalkeith-house, Edinburgh.* |
| 1818. Feb. 26. | Buckland, Very Rev. William, D.D., Dean of Westminster. F.L.S. V.P.G.S. Instit. Reg. Sc. Paris. Corresp., Acad. Sc. Bonon. Socc. Min. Imp. Petrop. et Cæs. Nat. Cur. Mosc., Socius. *Deanery, Westminster.* |
| 1836. Jan. 21. | † Budd, George, M.D. Coll. Reg. Med. Socius. 20 *Dover-street, Piccadilly; and Caius-college, Cambridge.* |
| 1840. May 21. | † Burge, William, Esq. 1 *Paper-buildings, Temple.* |
| 1829. Dec. 10. | Burlington, William, Earl of, M.A. Chancellor of the University of London.—F.G.S. 10 *Belgrave-square; and Hardwick-hall, Derbyshire.* |
| 1835. April 2. | Burnes, James, K.H. D.C.L. *India.* |
| 1837. Mar. 16. | † Burnet, John, Esq. *Egmont-house, Kensington.* |
| 1838. May 3. | † Burnet, Rev. Thomas, D.D., Rector of St. James, Garlickhythe. |
| 1833. Apr. 18. | † Burnett, Sir William, K.C.H. M.D.—VICE-PRESIDENT.—Coll. Reg. Med. Socius.—Acad. Med. et Chir. Petrop. Socius Honor. 5 *Somerset-place.* |
| 1814. Dec. 22. | Burney, Rev. Charles Parr, D.D. F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.A.S. M.R.S.L. *Rectory-house, Sible Hedingham, near Halsted, Essex.* |
| 1829. April 1. | Burns, John, M.D. *Glasgow.* |
| 1818. Feb. 26. | Burrow, Rev. Edward John, D.D. F.G.S. *Gibraltar.* |
| 1836. Mar. 17. | Burt, Major T. Seymour, M.R.A.S. *India.* |
| 1832. Dec. 6. | Burton, Decimus, Esq., F.S.A. 6 *Spring-gardens; and St. Leonard's, Hastings.* |

| Date of Election. | |
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| 1836. May 5. | † Burton, Edward, Esq., F.L.S. *Brooklyn, near Maidstone.* |
| 1844. Feb. 1. | † Bury, Edward, Esq. *Wolverton.* |
| 1818. Jan. 8. | Bute, John, Marquis of, D.C.L. F.S.A. F.R.A.S. *Camden-hill, Kensington; and Cardiff Castle, Glamorganshire.* |
| 1819. May 20. | Butler, The Very Rev. George, D.D. Dean of Peterborough, F.S.A. F.R.A.S. |
| 1822. Mar. 21. | Butter, John, M.D. F.L.S. *Plymouth; and Corringdon-hall, South Brent, Devonshire.* |
| 1841. May 6. | † Byng, Right Hon. George Stevens. 77 *Eaton-square.* |
| 1837. Jan. 19. | Cabbell, Benjamin Bond, Esq., F.S.A. 1 *Brick court, Temple.* |
| 1810. June 28. | Cadell, William Archibald, Esq., F.R.S.E. F.G.S. *Edinburgh.* |
| 1831. Mar. 10. | Caldcleugh, Alexander, Esq., F.L.S. F.G.S. *Chili.* |
| 1840. Feb. 20. | Caldecott, John, Esq., F.R.A.S. *Observatory, Travancore, India.* |
| 1796. Nov. 17. | Canterbury, Right Hon. William Howley, D.D., Lord Archbishop of, Trust. Brit. Mus. F.S.A. M.R.S.L. *Lambeth-palace.* |
| 1839. Feb. 14. | † Carington, Robert John, Lord. *Whitehall-yard; and Wycombe-abbey and Gayhurst, Bucks.* |
| 1826. Feb. 9. | Carleton, Hon. and Rev. Richard, M.A. *Greywell-hill, Odiham, Hampshire.* |
| 1814. May 19. | Carlisle, Nicholas, Esq., K.H. D.C.L. Hon. M.R.I.A. Sec. A.S. Soc. Reg. Antiq. Septen. Hafn., et Acad. Reg. Sc. Holm. Socius, Acad. Sc. et Lit. Panorm. Corresp. *Somerset-house.* |
| 1838. May 3. | † Carnac, Sir James Rivett, Bart. |
| 1818. May 28. | Carne, Joseph, Esq., M.R.I.A. F.G.S. *Penzance.* |
| 1844. Feb. 1. | † Carpenter, William Benjamin, M.D. 1 *Clarence-terrace, Stoke Newington.* |
| 1817. Feb. 13. | * Carpue, Joseph Constantine, Esq. 45 *Upper Charlotte-street, Fitzroy-square.* |
| 1800. Dec. 18. | Carrington, Sir Codrington Edmund, Knt. D.C.L. F.S.A. M.R.A.S. 32 *Russell-square.* |
| 1841. Feb. 11. | Cartwright, Samuel, Esq., F.L.S. 32 *Old Burlington-street.* |
| 1812. June 11. | Cawdor, John Frederick, Earl, Trust. Brit. Mus. F.G.S. 74 *South Audley-street; and Cawdor-castle, Nairn.* |
| 1828. Mar. 13. | Chambers, William Frederick, M.D. K.C.H. Physician to the Queen. Coll. Reg. Med. Socius. 46 *Brook-street.* |
| 1833. Feb. 7. | † Chandler, Very Rev. George, Dean of Chichester, D.C.L. M.R.S.L. R G.S. 36 *Mortimer-street.* |
| 1816. Nov. 21. | Chapman, Major-Gen. Sir Stephen Remnant, C.B. K.C.H. Royal Engineers. *Tainfield-house, Taunton, Somerset.* |
| 1836. Apr. 28. | † Chapman, John James, Esq., Capt. R.A. *Athenæum Club.* |
| 1842. May 26. | Chapman, Thomas, Esq., F.S.A. 14 *Montagu-place; and Whitby, Yorkshire.* |
| 1834. Feb. 6. | Chesney, Lieut.-Colonel Francis Rawdon, Royal Artillery. 11 *Wilton-terrace, Grosvenor-place.* |
| 1807. Mar. 12. | Children, John George, Esq., F.R.S.E. F.S.A. F.L.S. 48 *Torrington-square.* |
| 1826. Jan. 12. | Christie, Samuel Hunter, Esq., M.A.—SECRETARY.—F.R.A.S. F.C.P.S., Professor of Mathematics, Royal Military Academy. Acad. Sc. et Lit. Panorm., et Soc. Philom. Paris. Corresp. *Royal Military Academy, Woolwich.* |
| 1842. Apr. 14. | † Christmas, Rev. Henry, M.A. F.S.A. *Sion College, London Wall.* |
| 1833. Apr. 18. | Christopher, Robert Adam Dundas, Esq. 97 *Eaton-square.* |
| 1818. Dec. 10. | Churchill, Francis Almaric, Lord. *Cornbury-park, near Witney, Oxfordshire.* |
| 1832. June 7. | Clark, Sir James, Bart. M.D. Physician to the Queen. 22 *B, Brook-street.* |
| 1836. Jan. 28. | † Clark, William, M.D. *Cambridge.* |

| Date of Election. | | |
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| 1837. May 11. | † | Clark, William Tierney, Esq. *Hammersmith.* |
| 1825. June 9. | | Clarke, Sir Charles Mansfield, Bart. M.D., Coll. Reg. Med. Socius. *Wigginton-lodge, Tamworth; and* 14 *New Burlington-street.* |
| 1820. May 18. | | Clarke, Loftus Longueville, Esq., M.A. *India.* |
| 1841. Feb. 18. | † | Clendinning, John, M.D. Coll. Reg. Med. Socius. 16 *Wimpole-street.* |
| 1819. May 27. | | Clerk, Sir George, Bart. D.C.L. M.P. F.R.S.E. F.G.S. 8 *Park-street, Westminster.* |
| 1833. Apr. 18. | † | Clerke, Major Thomas Henry Shadwell, K.H. R.E. F.R.A.S. 4 *Brompton-grove.* |
| 1823. May 8. | | Clift, William, Esq., F.G.S. *Royal College of Surgeons, Lincoln's-inn-fields.* |
| 1820. Dec. 21. | | Cockburn, Vice-Admiral Right Hon. Sir George, G.C.B. G.C.H. F.R.A.S. |
| 1822. Nov. 21. | | Codrington, Vice-Admiral Sir Edward, G.C.B. *Admiralty-house, Portsmouth; and Hampton-lodge, Brighton.* |
| 1820. Apr. 13. | | Colby, Colonel Thomas, R.E. LL.D. F.R.S.E. Hon. M.R.I.A. F.G.S. F.R.A.S. M.R.A.S. *Ordnance Map Office, Southampton; and Dépôt Ordnance Survey of Ireland, Dublin.* |
| 1830. Feb. 18. | | Collier, Charles, M.D. F.G.S. 20 *Fitzroy-square.* |
| 1830. Jan. 14. | † | Colquhoun, Lieut.-Colonel James Nisbet, Royal Artillery. *Athenæum Club.* |
| 1819. Dec. 9. | | Conybeare, Rev. William Daniel, M.A. F.G.S. Instit. Reg. Sc. Paris. Corresp. *Axminster.* |
| 1840. June 4. | † | Cook, Thomas, Esq., Lieut. R.N. *Croydon, Surrey.* |
| 1829. June 18. | | Cooper, Bransby Blake, Esq. 2 *New-street, Spring-gardens.* |
| 1832. Dec. 6. | | Cooper, Charles Purton, Esq., LL.D. Hon. M.R.I.A. 7 *New Boswell-court, Lincoln's-inn.* |
| 1834. Feb. 6. | | Copeland, Thomas, Esq. 17 *Cavendish-square.* |
| 1833. Dec. 5. | † | Copland, James, M.D. Coll. Reg. Med. Socius, Soc. Amer. Philad. Socius. 5 *Old Burlington-street.* |
| 1821. May 24. | | Cotton, William, Esq., F.S.A. 3 *Crosby-square, Bishopsgate-street; and Walwood-house, Leytonstone.* |
| 1836. May 5. | † | Cox, William Sands, Esq. *Birmingham.* |
| 1812. Apr. 16. | | Crampton, Sir Philip Cecil, Bart. D.C.L. *Dublin.* |
| 1818. May 7. | | Crawford, John, Esq., F.L.S. F.G.S. M.R.A.S. |
| 1842. Dec. 22. | | Creuze, Augustin F. B., Esq. 14 *Grosvenor-place, New-road, Kennington.* |
| 1800. May 8. | * | Crichton, Sir Alexander, Knt. M.D. Grand Cross of St. Ann and St. Vladimir, F.L.S. F.G.S. Acad. Imp. Sc. Petrop., et Soc. Imp. Hist. Nat. Mosc., Socius.—Soc. Reg. Sc. Gotting. Corresp. *Seal Chart, near Sevenoaks, Kent.* |
| 1818. Mar. 5. | | Croft, Sir John, Bart. K.T.S. D.C.L. Acad. Reg. Olyssip. Socius. *Milgate, near Maidstone.* |
| 1810. July 5. | | Croker, Right Hon. John Wilson, LL.D. 6 *Park-street, Westminster.* |
| 1836. Feb. 18. | † | Crosse, John Green, M.D. Acad. Reg. Med. Paris., Soc. Reg. Med. Hafn. Med. Chir. Berolin., Soc. Amer. Philad. Socius. *Norwich.* |
| 1843. Dec. 7. | † | Crozier, Francis Rawdon Moira, Esq., Capt. R.N. |
| 1844. Feb. 29. | | Crum, Walter, Esq. *Thornlie Bank, near Glasgow.* |
| 1830. Apr. 1. | | Cubitt, William, Esq., M.R.I.A. F.R.A.S. 6 *Great George-street, Westminster.* |
| 1807. Jan. 22. | | Cuming, Lieut.-General Hon. John Leslie. |
| 1816. Jan. 11. | | Cumming, Rev. James, M.A., Professor of Chemistry, Cambridge, F.G. *Cambridge.* |
| 1838. Jan. 25. | † | Cureton, Rev. William, M.A. 37 *Queen Anne-street; and British Museum.* |
| 1841. May 27. | | Cursetjee, Ardaseer, Esq. *Bombay.* |
| 1834. Feb. 6. | † | Cust, Hon. Sir Edward, K.C.H. 30 *Hill-street.* |
| 1828. June 5. | † | Daniell, Edmund Robert, Esq. *Birmingham.* |

| Date of Election. | | |
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| 1822. Nov. 7. | | Dartmouth, William, Earl of, D.C.L. F.S.A. 23 *St. James's-square; and Sandwell-park, Birmingham.* |
| 1834. Jan. 29. | | Darwin, Charles, Esq., M.A. Sec. G.S. *Down, near Bromley, Kent.* |
| 1788. Feb. 21. | | Darwin, Robert Waring, M.D. *Shrewsbury.* |
| 1822. Dec. 19. | | Daubeny, Charles Giles Bridle, M.D., Aldrich's Professor of Chemistry, and Regius Professor of Botany, Oxford. Hon. M.R.I.A. F.L.S. F.G.S. Coll. Reg. Med. Socius. *Oxford.* |
| 1839. May 30. | † | Davenport, Edward Davies, Esq. 28 *Lower Brook-street; and Capesthorne, Cheshire.* |
| 1831. June 16. | | Davies, Griffith, Esq. *Palmer-terrace, Islington.* |
| 1833. Apr. 18. | | Davies, Thomas Stephens, Esq., F.R.S.E. F.S.A. *Royal Military Academy, Woolwich.* |
| 1841. May 20. | † | Davis, Hart, Esq. 17 *Oxford-square, Hyde-park.* |
| 1822. Mar. 28. | | Davis, Sir John Francis, Bart. *Portland-place; and Hollywood, near Compton, Bristol.* |
| 1826. Jan. 19. | | Davy, Edmund, Esq., Prof. of Chemistry to the Royal Dublin Society, M.R.I.A. *Dublin.* |
| 1814. Feb. 17. | | Davy, John, M.D. F.R.S.E. Inspector-General of Army Hospitals. *Barbadoes; and Ambleside, Westmoreland.* |
| 1815. Mar. 9. | | Dawkins, James Colyer, Esq., F.S.A. *Ham-common, Richmond.* |
| 1811. Feb. 28. | | Dealtry, Rev. William, D.D. F.R.A.S. *Clapham-common.* |
| 1819. Dec. 23. | | De la Beche, Sir Henry Thomas, Knt. F.L.S. F.G.S., Director of the Ordnance Geological Survey of Great Britain. *Museum of Economic Geology,* 6 *Craig's-court, Charing-cross.* |
| 1839. Feb. 28. | † | Denham, Henry Mangles, Esq., Commander R.N. 89 *Pall Mall; and Port Fleetwood.* |
| 1841. May 20. | † | Denham, Rev. Joshua Frederick, M.A. 1 *New Inn.* |
| 1838. Feb. 22. | | Denison, William Thomas, Esq., Lieut. R.E. F.R.A.S. F.R.G.S. *Wood-street, Woolwich.* |
| 1833. June 20. | † | Denman, Thomas, Lord. 38 *Portland-place; and Stoney Middleton, Derbyshire.* |
| 1829. Feb. 19. | | D'Eyncourt, Right Hon. Charles Tennyson, F.S.A. 5 *Albemarle-street.* |
| 1845. Mar. 6. | † | Dickenson, John, Esq., F.G.S. F.R.G.S. F.A.S. *Abbott's-hill, Hemel Hempstead.* |
| 1804. Feb. 2. | | Dillwyn, Lewis Weston, Esq., F.L.S. F.G.S. *Sketty-hall, near Swansea.* |
| 1832. June 7. | † | Disney, John, Esq., F.S.A. *The Hyde, near Ingatestone, Essex.* |
| 1811. Mar. 21. | | Dixon, Rev. Richard, M.A. *Niton, Isle of Wight.* |
| 1835. June 4. | † | Dobson, Sir Richard, Knt. *Royal Hospital, Greenwich.* |
| 1819. Dec. 23. | | Dollond, George, Esq., F.R.A.S. 59 *St. Paul's Churchyard; and North-terrace, Camberwell.* |
| 1838. Jan. 18. | † | Donkin, Bryan, Esq., F.R.A.S. 6 *Paragon, Kent-road.* |
| 1842. Jan. 13. | † | Donkin, William Fishburn, Esq., M.A., Savilian Professor of Astronomy in the University of Oxford. *Oxford.* |
| 1830. Jan. 28. | | Douglas, George, Esq. *Chilston, Kent.* |
| 1816. Jan. 25. | * | Douglas, Major-General Sir Howard, Bart. C.B. K.S.C. D.C.L. F.S.A. 15 *Green-street, Grosvenor-square.* |
| 1826. Mar. 9. | | Douglas, William Robert Keith, Esq. |
| 1815. Mar. 16. | | D'Oyley, Rev. George, D.D. *Rectory, Lambeth.* |
| 1836. Feb. 4. | † | Drory, George William, Esq. 38 *Westbourne-terrace, Hyde-park.* |
| 1839. Dec. 19. | † | Drummond, Henry, Esq. *Albury-park, Guildford, Surrey.* |
| 1808. Dec. 8. | | Duckett, Sir George, Bart. M.A. F.S.A. F.G.S. Hon. M.R.I.S. |
| 1825. Mar. 10. | | D'Urban, Major-General Sir Benjamin, K.C.B. K.C.H. K.T.S. |
| 1824. Feb. 19. | | Durham, Edward Maltby, D.D. Lord Bishop of, F.S.A. 4 *Upper Portland-place; and Auckland-castle, Durham.* |

| Date of Election. | | |
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| 1799. Apr. 11. | | East, Right Hon. Sir Edward Hyde, Bart. M.R.A.S. *Palladium-office, Waterloo-place; and Sherwood-lodge, Battersea.* |
| 1838. Jan. 25. | † | Eastlake, Charles Locke, Esq., R.A. 13 *Upper Fitzroy-street.* |
| 1835. Feb. 5. | † | Edye, John, Esq. 9 *Mecklenburg-square.* |
| 1841. Jan. 21. | † | Edye, Joseph, Esq. *Portsmouth.* |
| 1831. Feb. 10. | | Egerton, Sir Philip de Malpas Grey, Bart. F.G.S. 30 *Eaton-place; and Oulton-park, Cheshire.* |
| 1815. Mar. 2. | | Elliot, Sir William Francis, Bart. *Stobb's-castle; and Wells, N.B.* |
| 1834. June 5. | | Elliot, Hon. George, Capt. R.N. |
| 1829. Mar. 19. | | Elliotson, John, M.D. Coll. Reg. Med. Socius. 37 *Conduit-street.* |
| 1835. Nov. 26. | † | Elliott, Charles, Esq. 47 *Portland-place.* |
| 1832. Apr. 5. | | Elliott, Rev. Charles Boileau, M.A. 47 *Portland-place; and Tattingstone, Suffolk.* |
| 1811. May 30. | * | Ellis, Sir Henry, K.H. B.C.L. Sec. S.A. Hon. M.R.I.A. Hist. Scand. Holm. et Soc. Reg. Antiq. Hafn. Socius.—Soc. Reg. Antiq. Franc. Corresp. Principal Librarian of the British Museum. *British Museum.* |
| 1819. Feb. 11. | | Ellis, Right Hon. Henry, F.G.S. |
| 1801. Mar. 12. | | Ellis, John, Esq., F.L.S. |
| 1832. June 7. | † | Elphinstone, Howard, Esq., M.A. F.G.S. 19 *Eaton-place, Belgrave-square.* |
| 1841. Jan. 14. | | Enderby, Charles, Esq., F.L.S. *Greenwich.* |
| 1829. Jan. 15. | | Enniskillen, William Willoughby, Earl of, D.C.L. F.G.S. *Athenæum Club; and Florence-court, Fermanagh, Ireland.* |
| 1827. Mar. 8. | | Everest, Lieut.-Colonel George, Bengal Artillery, F.G.S. F.R.A.S. M.R.A.S. Surveyor-General of India. 16 *Bury-street, St. James's.* |
| 1840. May 21. | † | Ewer, Walter, Esq. 23 *Hanover-square.* |
| 1845. Feb. 13. | † | Falconer, Hugh, M.D. F.L.S. F.G.S. *Oriental Club, Hanover-square.* |
| 1824. Jan. 8. | | Faraday, Michael, Esq., D.C.L., Fullerian Professor of Chemistry in the Royal Institution of Great Britain. Hon. Mem. R.S.E., and C.P.S. F.G.S. Instit. Reg. (Acad. Sc.) Paris. Socius, Acad. Imp. Sc. Petrop. Socius Honor.—Acad. Reg. Sc. Holm., Soc. Reg. Sc. Hafn., Acad. Reg. Sc. Mut., Acad. Amer. Art. et Sc. Bost. Socius, Acad. Reg. Sc. Berol., Soc. Georg. Florent., Soc. Philom. Paris., et Acad. Reg. Med. Paris. Corresp. 21 *Albemarle-street.* |
| 1839. May 2. | † | Farre, Arthur, M.D. Coll. Reg. Med. Socius. 22 *Curzon-street, May-fair.* |
| 1835. April 2. | † | Featherstonhaugh, G. W., Esq. *Havre.* |
| 1816. Feb. 29. | | Fellowes, Sir James, Knt. M.D. Coll. Reg. Med. Socius. *Pangbourne-lodge, near Reading.* |
| 1836. Mar. 3. | | Field, Joshua, Esq. *Cheltenham-place, Lambeth.* |
| 1842. May 5. | † | Fielding, George Hunsley, M.D. *Ashford, Kent.* |
| 1825. Jan. 27. | | Fisher, Rev. George, M.A. F.R.A.S. *Royal Hospital, Greenwich.* |
| 1815. Nov. 9. | | Fitton, William Henry, M.D. F.L.S. F.G.S. F.R.A.S. Coll. Reg. Med. Socius. 53 *Upper Harley-street.* |
| 1811. Jan. 17. | | Fitzwilliam, Charles William, Earl, F.S.A. F.G.S. *Mortimer-house, Grosvenor-place; and Wentworth-house, near Rotherham, Yorkshire.* |
| 1839. Mar. 21. | | Fletcher, Thomas William, Esq., F.S.A. *Dudley, Worcestershire.* |
| 1834. Apr. 10. | † | Folkes, Sir William Browne, Bart. *Hillington-hall, Lynn.* |
| 1845. Feb. 13. | † | Forbes, Edward, Esq., F.L.S. F.G.S. Professor of Botany at King's College. Palæontologist to the Geological Survey of Great Britain. *King's College.* |

| Date of Election. | |
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| 1832. June 7. | Forbes, James David, Esq., Professor of Natural Philosophy in the University of Edinburgh. Sec. R.S.E. F.G.S. Instit. Reg. Sc. Paris. Corresp. *Edinburgh.* |
| 1829. Feb. 5. | Forbes, John, M.D. Coll. Reg. Med. Socius. 12 *Old Burlington-street.* |
| 1822. Feb. 21. | Forbes, William Nairn, Esq., F.G.S. |
| 1828. June 12. | † Forshall, Rev. Josiah, M.A. F.S.A. Hon. M.R.I.A. M.R.S.L. *British Museum.* |
| 1821. Feb. 22. | Forster, Edward, Esq., V.P.L.S. 11 *Mansion-house-street; and Woodford, Essex.* |
| 1817. June 5. | Fortescue, Hugh, Earl. 17 *Grosvenor-square; and Castle-hill, Southmolton.* |
| 1802. April 1. | Fowler, Richard, M.D. F.S.A. *Salisbury.* |
| 1845. Feb. 13. | Fownes, George, Esq., Professor of Practical Chemistry, University College, London. |
| 1823. Feb. 20. | Franklin, Sir John, Knt. Capt. R.N. D.C.L. F.L.S. V.P.R.G.S. F.G.S. F.R.A.S. Soc. Geogr. Paris. Corresp. |
| 1821. Dec. 12. | Franks, William, Esq., M.A. *Wood-hill, Hatfield, Hertfordshire.* |
| 1837. June 8. | Frere, George Edward, Esq. *Twerton, near Bath.* |
| 1834. Apr. 10. | † Freshfield, James William, Esq., F.G.S. 15 *Regent-street; and Leatherhead, Surrey.* |
| 1820. Mar. 16. | Friend, Matthew Curling, Esq., Lieut. R.N. *George Town, Van Diemen's Land.* |
| 1839. Jan. 10. | † Frodsham, William James, Esq. *Change-alley, Cornhill.* |
| 1834. Dec. 18. | † Galloway, Thomas, Esq., M.A. F.R.A.S. 45 *Torrington-square.* |
| 1816. April 4. | Gardiner, Rev. Samuel John, M.A. |
| 1839. Mar. 21. | Gaskin, Rev. Thomas, M.A. F.R.A.S. *Jesus College, Cambridge.* |
| 1840. April 9. | † Gassiot, John P., Esq. *Clapham-common.* |
| 1796. Feb. 18. | Gibbes, Sir George Smith, Knt. M.D. F.L.S. Coll. Reg. Med. Socius. 2 *Oriel-place, Cheltenham.* |
| 1834. Apr. 10. | Gilbert, John Davies, Esq., M.A. *Eastbourne, Sussex; and Tredrea, Cornwall.* |
| 1828. Mar. 27. | Glenelg, Charles, Lord, D.C.L. M.R.S.L. *Glenelg, Inverness; and* 91 *Wimpole-street.* |
| 1838. Feb. 8. | Glynn, Joseph, Esq. *Butterley, Derbyshire.* |
| 1839. Mar. 7. | † Godwin, George, jun., Esq., F.S.A. 11 *Pelham-crescent, Brompton.* |
| 1808. May 26. | Goldingham, John, Esq., F.R.A.S. M.R.A.S. *Worcester.* |
| 1828. Mar. 13. | Goldsmid, Sir Isaac Lyon, Bart. F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.S.L. *Park-lodge, Regent's-park.* |
| 1819. Jan. 29. | Gompertz, Benjamin, Esq., F.R.A.S. *Kennington-terrace, Vauxhall.* |
| 1835. April 2. | † Gordon, James Alexander, M.D. Coll. Reg. Med. Socius. 71 *Lower Grosvenor-street.* |
| 1801. June 11. | Gordon, Lieut.-General Sir James Willoughby, Bart. K.C.B. G.C.H. *Near the Royal Hospital, Chelsea.* |
| 1830. Dec. 9. | Gordon, Henry Percy, Esq., M.A. *Near the Royal Hospital, Chelsea.* |
| 1821. Feb. 8. | Gordon, Thomas, Esq. *Zante, Ionian Islands.* |
| 1820. Apr. 27. | Goulburn, Right Hon. Henry, D.C.L. 11 *and* 12 *Downing-street.* |
| 1843. Jan. 19. | Gould, John, Esq., F.L.S. 20 *Broad-street, Golden-square.* |
| 1831. Dec. 22. | Graham, Right Hon. Sir James R. G., Bart. 31 *Hill-street; and Netherby, Cumberland.* |
| 1836. Dec. 25. | Graham, Thomas, Esq., M.A. Professor of Chemistry, University College, London. F.G.S. Hon. Memb. R.S.E. National Inst. Washington, U.S. et Acad. Reg. Sc. Berolin. et Monach. Corresp. 9 *Torrington-square.* |
| 1840. May 21. | † Grant, Thomas Tassell, Esq. *Royal Clarence Victualling-yard, Portsmouth.* |
| 1836. Feb. 4. | Grant, Robert Edmond, M.D. F.R.S.E. F.L.S. Professor of Comparative Anatomy and Zoology in University College. 10 *Grafton-place, Euston-square.* |

| Date of Election. | |
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| 1817. Nov. 20. | Granville, Augustus Bozzi, M.D. F.G.S. M.R.A.S. Acadd. Reg. Sc. Brux., Acadd. Luc. et Pat.: Socc. Geogr. Flor., Ital., Vienn., Sc. Nat. Neap., Athen. Ven., Philom. Paris., Socius.—Acad. Imp. Sc. Petrop. et Reg. Taurin. Corresp. 109 *Piccadilly; and Rosemont, Great Missenden, Buckinghamshire.* |
| 1832. Feb. 2. | Gravatt, William, Esq. 34 *Parliament-street.* |
| 1839. Apr. 18. | Graves, John Thomas, Esq., M.A. 8 *Gray's-inn-square.* |
| 1832. Feb. 2. | Gray, John Edward, Esq., F.G.S. F.R.G.S. Soc. Imp. Hist. Nat. Mosc. Acadd. Lync. Romæ, Sc. Nat. Philad. et Hist. Nat. Boston., Socius. *British Museum.* |
| 1825. Feb. 24. | Green, Joseph Henry, Esq., Professor of Anatomy to the Royal Academy, F.G.S. *Barnet.* |
| 1807. Mar. 5. | Greenough, George Bellas, Esq., F.L.S. F.G.S. M.R.A.S. *Grove-house, Regent's-park.* |
| 1833. Feb. 7. | Greig, Woronzow, Esq., M.A. 14 *Lower Belgrave-street, Eaton-square.* |
| 1830. June 10. | Gresswell, Rev. Richard, M.A. *Worcester College, Oxford.* |
| 1815. Feb. 16. | Grey, Sir Thomas, Knt. M.D. F.L.S. *Ramsgate.* |
| 1841. Apr. 29. | † Grey, Thomas Philip, Earl de. 4 *St. James's-square; and West-park, Silsoe, Bedfordshire.* |
| 1834. Apr. 10. | † Griffith, Edward, Esq., F.S.A. *Downshire-hill, Hampstead.* |
| 1806. May 1. | Griffiths, John, Esq. |
| 1840. Nov. 26. | Grove, William Robert, Esq., M.A. V.P.R.I. Ph. D. Soc. Phil. Basil. Socius Honor. 27 *Upper Gloucester-place, Dorset-square; and* 4 *Hare-court, Temple.* |
| 1830. Apr. 22. | Grover, Capt. John, F.R.A.S. *Army and Navy Club.* |
| 1839. June 20. | Guest, Edwin, Esq. 4 *King's-bench-walk, Temple.* |
| 1830. June 10. | Guest, Sir Josiah John, Bart. F.G.S. 8 *Spring-gardens; and Dowlais Iron-works, Glamorganshire.* |
| 1839. Mar. 7. | Gulliver, George, Esq. *Regent's-park Barracks.* |
| 1818. Jan. 15. | Gurney, Hudson, Esq., V.P.S.A. M.R.S.L. 9 *St. James's-square; and Keswick-hall near Norwich.* |
| 1827. May 24. | Guthrie, George James, Esq. 4 *Berkeley-street, Piccadilly.* |
| 1844. Apr. 18. | † Haddington, Right Hon. Thomas, Earl of. *Tyningham-castle, Dunbar.* |
| 1801. May 7. | Hailstone, Rev. John, M.A. F.L.S. F.G.S. *Trumpington, Cambridgeshire.* |
| 1820. Apr. 27. | * Hall, Sir John, Bart. F.R.S.E. F.G.S. *Dunglass, Dunbar, Haddingtonshire.* |
| 1832. April 5. | Hall, Marshall, M.D. F.R.S.E. Coll. Reg. Med. Socius. 14 *Manchester-square.* |
| 1827. Nov. 22. | Hall, Thomas Henry Esq., M.A. 49 *Tavistock-square.* |
| 1821. Mar. 8. | Hallam, Henry, Esq., M.A. Trust. Brit. Mus. V.P.S.A. F.G.S. F.R.A.S. M.R.S.L. Instit. Reg. Sc. Paris. Socius. 24 *Wilton-crescent, Knightsbridge.* |
| 1839. May 30. | † Halliwell, James Orchard, Esq., Hon. M.R.I.A. F.S.A.L. & E. F.R.A.S. Hon. M.R.S.L., Socc. Reg. Antiq. Franc., Reg. Antiq. Septen. Hafn., Ethnol. Paris., Reg. Geogr. Paris., Asiatic. Paris., Corresp. 10 *Fitzroy-street; and Islip, Oxfordshire.* |
| 1835. Feb. 5. | † Hamett, Sir John, Knt. M.D. Deputy Medical Inspector of Hospitals and Fleets. |
| 1808. Jan. 14. | Hamilton and Brandon, Alexander, Duke of, F.S.A. 12 *Portman-square; and Hamilton-palace, Lanarkshire.* |
| 1828. Jan. 17. | Hamilton, Rev. H. Parr, M.A. F.G.S. F.R.A.S. *Wath Rectory, near Ripon.* |
| 1813. April 8. | Hamilton, William Richard, Esq., V.P.S.A. For. Sec. R.S.L. Acad. Reg. Sc. Berolin. Socius Honor. 12 *Bolton-row, May-fair.* |
| 1838. Jan. 18. | † Hansler, Sir John Jacob, Knt. F.S.A. 52 *Upper Bedford-place, Russell-square.* |
| 1824. Apr. 29. | Harcourt, Rev. W. Venables Vernon, M.A. Hon. M.R.I.A. F.G.S. *Weldrake, near York.* |

| Date of Election. | | |
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| 1838. April 5. | † | Hardwick, John, Esq., D.C.L. 5 *K, Albany, Piccadilly.* |
| 1831. Dec. 8. | | Hardwick, Philip, Esq., R.A. F.S.A. 60 *Russell-square.* |
| 1839. Jan. 17. | † | Hardy, Peter, Esq. 37 *Old Jewry; and Addiscombe, near Croydon.* |
| 1823. May 29. | | Harford, John Scandret, Esq., D.C.L. |
| 1844. Apr. 18. | † | Hargreave, Charles James, Esq., B.L. Professor of Jurisprudence, University College, London. 69 *Chancery-lane.* |
| 1835. Feb. 5. | † | Harris, John Greathed, Esq., M.A. 2 *Old Palace-yard.* |
| 1831. June 2. | | Harris, William Snow, Esq. *Windsor Villas, Plymouth.* |
| 1845. May 8. | † | Harrison, Thomas Charles, Esq. 31 *York-terrace, Regent's-park.* |
| 1825. Feb. 17. | | Harvey, Henry, Esq., F.R.A.S. 59 *Regency-square, Brighton.* |
| 1835. April 2. | † | Harvey, Major-General Sir Robert John, C.B. K.T.S. K.S.B. F.S.A. *United Service Club; and Mousehold-house, near Norwich.* |
| 1827. May 24. | † | Harwood, John, M.D. F.L.S. *St. Leonard's, Hastings.* |
| 1812. Jan. 9. | | Hasted, Rev. Henry, M.A. F.L.S. *Bury, Suffolk.* |
| 1797. ~~Mar. 9.~~ | | Hatchett, Charles, Esq., F.R.S.E. F.S.A. F.L.S. Instit. Reg. Sc. Paris. Corresp.—Acad. Reg. Sc. Monach., et Soc. Œcon. Petrop., Socius. *Belle-Vue-house, Chelsea; and Bollington, Lincolnshire.* |
| 1821. Nov. 15. | | Haughton, Sir Graves Chamney, K.H. M.A. Hon. M.R.I.A. M.R.A.S., Instit. Reg. Sc. Paris. Socius, Acad. Reg. Berolin. Corresp. 14 *Grafton-street, Bond-street.* |
| 1834. Dec. 18. | | Hawkins, Bissett, M.D. Coll. Reg. Med. Socius. 30 *Golden-square.* |
| 1821. May 24. | * | Hawkins, Edward, Esq., F.S.A. F.L.S. *British Museum.* |
| 1791. May 5. | | Hawkins, John, Esq. *Quay-house, Devonshire.* |
| 1830. June 10. | | Hawkins, John Heywood, Esq., M.A. F.G.S. 16 *Suffolk-street; and Bignor-park, Petworth, Sussex.* |
| 1835. Nov. 19. | † | Hawkins, Rev. William B. L., M.A. 23 *Great Marlborough-street.* |
| 1814. Mar. 3. | | Hay, Robert William, Esq., F.S.A. |
| 1818. May 28. | * | Heath, George Crauford, Esq. *Cambridge.* |
| 1843. Feb. 2. | † | Heath, John Benjamin, Esq., F.S.A. 66 *Russell-square.* |
| 1834. Apr. 10. | | Henry, William Charles, M.D. *Haffield, near Ledbury, Herefordshire.* |
| 1840. Feb. 27. | † | Henwood, William Jory, Esq. 4 *Clarence-street, Penzance.* |
| 1813. May 27. | | Herschel, Sir John Frederick William, Bart. D.C.L. M.A. Trust. Brit. Mus. F.R.S.E. Hon. M.R.I.A. F.G.S. M.C.P.S. Instit. Reg. Sc. Paris. Corresp.—Acadd. Imp. Sc. Petrop., Reg. Berol., Taurin. Neap. et Brux.: Socc. Reg. Gotting., Hafn. et Harl.: Acadd. Lync. Romæ, Pat., Bonon., Panorm., Gioen. Catan. et Divion. ex intim., Socc. Philom. Paris., Ital. Mut., Helvet., Socius. *Collingwood, near Hawkhurst, Kent.* |
| 1843. April 6. | | Heygate, James, M.D. *College-house, Derby.* |
| 1843. Jan. 19. | | Heywood, Sir Benjamin, Bart. 9 *Hyde-park-gardens; and Claremont, Manchester.* |
| 1839. Feb. 7. | | Heywood, James, Esq., F.S.A. *Athenæum Club; and Acresfield, Manchester.* |
| 1820. Mar. 23. | | Higman, Rev. John Philip, M.A. F.G.S. F.R.A.S. *Trinity College, Cambridge.* |
| 1839. Jan. 10. | † | Hilton, John, Esq. 10 *New Broad-street.* |
| 1809. Dec. 21. | | Hoare, Charles, Esq., F.S.A. 37 *Fleet-street.* |
| 1814. May 19. | | Hobhouse, Right Hon. Sir John Cam, Bart. M.A. 42 *Berkeley-square.* |
| 1811. June 27. | | Hoblyn, Thomas, Esq., F.L.S. |
| 1841. Feb. 18. | | Hodgkinson, Eaton, Esq., F.G.S. 14 *Salford-crescent, Manchester.* |

| Date of Election. | | |
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| 1831. Apr. 14. | | Hodgson, Joseph, Esq. *Birmingham.* |
| 1839. June 20. | † | Hogg, John, Esq., M.A. F.L.S. F.C.P.S. M.R.S.L. 12 *King's-bench-walk, Inner Temple; and Norton-house, Stockton-upon-Tees.* |
| 1837. Jan. 19. | | Holland, Charles, M.D. 16 *Queen-street, May-fair.* |
| 1815. Jan. 19. | | Holland, Henry, M.D. F.G.S. Coll. Reg. Med. Socius. 25 *Brook-street.* |
| 1826. Feb. 2. | | Holman, James, Esq., Lieut. R.N. F.L.S. *Windsor.* |
| 1825. Apr. 21. | | Home, Sir Everard, Bart. Capt. R.N. F.S.A. H.M. Ship North Star. |
| 1843. Dec. 7. | | Hood, Charles, Esq., F.R.A.S. *Earl-street, Blackfriars; and Camberwell.* |
| 1812. Jan. 9. | | Hooker, Sir William Jackson, K.H. LL.D. Hon. M.R.I.A. F.S.A. F.L.S. F.G.S. Acad. Cæs. Nat. Cur. Socius. *Kew.* |
| 1834. June 5. | † | Hope, Rev. Frederick William, M.A. F.L.S. 56 *Upper Seymour-street.* |
| 1837. June 1. | † | Hopkins, William, Esq., M.A. *Fitzwilliam-street, Cambridge.* |
| 1841. May 20. | | Hoppus, Rev. John, LL.D. Ph.D. Professor of Philosophy and Logic, University College, London. 39 *Camden-street, Camden-town.* |
| 1834. Feb. 6. | | Horne, James, Esq. *Clapham-common.* |
| 1813. Nov. 11. | | Horner, Leonard, Esq., F.R.S.E.—Vice-President.—President of the Geological Society. Soc. Sc. Harlem. Socius. 2 *Bedford-place.* |
| 1828. Jan. 10. | † | Horsfield, Thomas, M.D. F.L.S. F.G.S. M.R.A.S. Acad. Cæs. Nat. Cur. Socius. 43 *Markham-square, King's-road, Chelsea.* |
| 1843. May 25. | | Hoskins, Samuel Elliott, M.D. *Guernsey.* |
| 1794. April 3. | | Howard, Colonel Hon. Fulk Greville, F.S.A. 16 *Grosvenor-square.* |
| 1821. Mar. 8. | | Howard, Luke, Esq. *Bruce-grove, Tottenham; and Ackworth-villa, Pomfret.* |
| 1834. Apr. 10. | | Hudson, Robert, Esq., F.G.S. *Clapham-common.* |
| 1818. Jan. 8. | | Hume, Joseph, Esq. 6 *Bryanston-square.* |
| 1819. Nov. 11. | | Hunt, Rev. George, M.A. F.S.A. *Egg Buckland, near Plymouth.* |
| 1837. April 6. | † | Hunter, Robert, Esq., F.G.S. F.S.A. *Highgate.* |
| 1819. Nov. 18. | | Hustler, Rev. James Devereux, B.D. *Euston-rectory, near Thetford, Norfolk.* |
| 1829. Mar. 19. | | Hutchinson, Lieut.-Colonel George, E.I.C.S. Be. Engineers. 18 *Gloucester-place, Portman-square.* |
| 1840. June 4. | † | Hutton, William, Esq. *Newcastle-upon-Tyne.* |
| 1844. Feb. 29. | † | Hyett, William Henry, Esq. *Painswick-house, Painswick.* |
| 1838. May 31. | | Hymers, Rev. John, D.D. *St. John's College, Cambridge.* |
| 1813. Mar. 4. | | Inglis, Sir Robert Harry, Bart. LL.D. Trust. Brit. Mus. F.S.A. F.R.A.S. 7 *Bedford-square.* |
| 1807. Apr. 23. | | Jacob, William, Esq., Instit. Sc. Paris. Corresp. 31 *Cadogan-place, Sloane-street.* |
| 1845. Apr. 3. | † | Jackson, Colonel Julian, Secretary to the R.G.S. *Royal Geographical Society; and* 52 *Coleshill-street, Pimlico.* |
| 1826. May 25. | | Jameson, Robert, Esq., Regius Professor of Natural History, Edinburgh. F.R.S.E. Hon. M.R.I.A. F.L.S. F.G.S. Acad. Reg. Sc. Neap.: Socc. Reg. Sc. Dan., Imp. Hist. Nat. Mosc., Hist. Nat. Veter. et Paris., Philom. Paris., Amer. Philad., Phil. et Hist. Nov.-Ebor., Socius.—Acad. Reg. Sc. Berol. Corresp. *Edinburgh.* |
| 1841. Jan. 7. | † | Jeffereys, Julius, Esq. 25 *A, Norfolk-crescent, Hyde-park.* |
| 1840. April 2. | † | Jeffreys, John Gwyn, Esq., F.L.S. *Swansea.* |
| 1841. Feb. 18. | † | Jenkins, Sir Richard, G.C.B. 7 *Mansfield-street, Portland-place; and Bickton-hall, Shrewsbury.* |
| 1821. Mar. 1. | | Jennings, Rev. Philip, D.D. *Hampstead-green.* |

| Date of Election. | | |
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| 1838. Mar. 15. | † | Jervis, Thomas Best, Esq., Major E.I.C.E. F.L.S. F.G.S. F.R.A.S. |
| 1842. May 5. | † | Jesse, John, Esq., F.R.A.S. F.L.S. *Ardwick, near Manchester.* |
| 1842. Mar. 10. | † | Johnson, Cuthbert William, Esq. 14 *Gray's-inn-square.* |
| 1836. Mar. 10. | † | Johnson, Edward John, Esq. Captain R.N. 13 *Clement's-inn.* |
| 1838. Jan. 18. | | Johnson, Rev. George Henry Sacheverell, M.A. Professor of Moral Philosophy in the University of Oxford. *Oxford.* |
| 1810. Nov. 22. | | Johnston, Right Hon. Sir Alexander, Knt. F.S.A. V.P.R.A.S. 19 *Great Cumberland-place; and York-house, Twickenham.* |
| 1845. June 5. | † | Johnston, Alexander Robert, Esq. |
| 1837. June 15. | † | Johnston, James F. W., Esq., M.A. F.R.S. Ed. Professor of Chemistry and Mineralogy in the University of Durham. *Durham.* |
| 1835. June 4. | † | Jones, Thomas, Esq., F.R.A.S. 62 *Charing-cross; and West-square.* |
| 1844. Mar. 21. | † | Jones, Thomas Rymer, Esq. *King's-college; and* 120 *Camden-road Villas.* |
| 1840. Apr. 30. | † | Jones, Thomas Wharton, Esq. 35 *George-street, Hanover-square.* |
| 1840. Nov. 19. | | Kater, Edward, Esq., F.G.S. M.R.I.A. *Mexborough, Yorkshire; and Athenæum Club.* |
| 1838. Dec. 6. | † | Kelland, Rev. Philip, M.A. F.R.S.E. M.C.P.S. Professor of Mathematics in the University of Edinburgh. *Edinburgh.* |
| 1844. Feb. 29. | † | Kerigan, Thomas, Esq., R.N. 9 *St. Paul's-square, Southsea, Portsmouth.* |
| 1841. Mar. 18. | † | Kerrison, Robert Masters, M.D. 12 *New Burlington-street.* |
| 1822. Mar. 28. | | Kidd, John, M.D. Regius Professor of Medicine, and Aldrich's Professor of Anatomy, Oxford, F.L.S. F.G.S. Coll. Reg. Med. Socius. *Oxford.* |
| 1834. Dec. 18. | | Kiernan, Francis, Esq. 30 *Manchester-street, Manchester-square.* |
| 1824. Feb. 26. | | King, Philip Parker, Esq. Captain R.N. F.L.S. *Dunheved, New South Wales.* |
| 1818. Mar. 5. | | Kirby, Rev. William, M.A. F.L.S. F.G.S. Acad. Cæs. Nat. Cur., et Soc. Nat. Scrutat. Berol. Socius. *Barham, near Ipswich.* |
| 1841. May 20. | † | Knight, Henry Gally, Esq., F.L.S. 69 *Grosvenor-street.* |
| 1830. Mar. 4. | | Knowles, Sir Francis Charles, Bart. M.A. |
| 1810. Jan. 18. | * | Konig, Charles, Esq., K.H. Hon. M.R.I.A. F.L.S. Acad. Reg. Sc. Monach. Socius.—Acad. Imp. Sc. Petrop., et Soc. Reg. Gotting. Corresp.—Soc. Imp. Hist. Nat. Mosc. Socius.—Acad. Panorm., et Soc. Veterav., Sodalis. *British Museum.* |
| 1843. Nov. 23. | | Laing, Rev. David. 62 *Mornington-road, Regent's-park.* |
| 1811. April 4. | | Lansdowne, Henry, Marquis of, D.C.L. Trust. Brit. Mus. M.R.S.L. 52 *Berkeley-square; and Bowood-park, Wiltshire.* |
| 1844. May 16. | | Larcom, Thomas Aiskew, Capt. R.E. |
| 1813. Nov. 11. | | Lawrence, William, Esq. 18 *Whitehall-place.* |
| 1840. May 21. | † | Lawson, Henry, Esq. 7 *Lansdowne-crescent, Bath.* |
| 1815. Apr. 13. | | Leake, Lieut.-Colonel William Martin, M.R.S.L. Acad. Reg. Sc. Berol. Socius Honor. Instit. Reg. Paris. Corresp. 50 *Queen-Anne-street.* |
| 1843. May 11. | † | Le Couteur, Colonel John. *Belle Vue, Jersey.* |
| 1831. Feb. 24. | | Lee, John, LL.D. F.R.A.S. 5 *College, Doctors'-commons; and Hartwell-house, near Aylesbury, Buckinghamshire.* |
| 1830. Mar. 25. | | Lee, Robert, M.D. Coll. Reg. Med. Socius. 4 *Saville-row.* |
| 1820. Nov. 16. | | Lefevre, John George Shaw, Esq., M.A. Vice-Chancellor of the University of London. *Board of Trade, Whitehall.* |
| 1817. June 12. | | Legh, Thomas, Esq., D.C.L. *Lyme-park, Cheshire.* |

| Date of Election. | | |
|---|---|---|
| 1822. May 23. | | Lemon, Sir Charles, Bart. 46 *Charles-street, Berkeley-square; and Carclew, near Falmouth, Cornwall.* |
| 1836. May 5. | † | Lewis, Thomas Locke, Esq. Capt. R.E. F.G.S. *Ibsley-cottage, Exeter.* |
| 1811. Mar. 7. | | Lincoln, John Kaye, Lord Bishop of. *Cambridge; and Buckden-palace, Huntingdonshire.* |
| 1828. Jan. 17. | † | Lindley, John, Phil. D. F.L.S. Acad. Reg. Berol. Corresp.; Acad. Cæs. Nat. Cur., Socc. Physiogr. Lund., Linn. Holm., Socius.—Soc. Batav. Sc., Lyc. Nat. Hist. Nov.-Ebor., Socius Honor.—Prof. Bot. Univ. Coll. Lond. 21 *Regent-street.* |
| 1832. Feb. 2. | | Lister, Joseph Jackson, Esq. *Upton, Essex.* |
| 1841. May 13. | † | Liston, Robert, Esq. 5 *Clifford-street, New Bond-street.* |
| 1836. Feb. 4. | | Llewelyn, John Dillwyn, Esq., F.L.S. *Penllegare, Glamorgan.* |
| 1818. Mar. 12. | | Lloyd, Edward, Esq. Captain R.N. |
| 1830. Mar. 11. | † | Lloyd, John Augustus, Esq. *Port Louis, Mauritius.* |
| 1834. Apr. 10. | | Lloyd, Rev. William Forster, M.A. *Missenden, Bucks.* |
| 1836. Jan. 21. | | Lloyd, Rev. Humphrey, M.A. M.R.I.A. *Dublin.* |
| 1838. Feb. 22. | † | Locke, Joseph, Esq. 6 *Chester-terrace, Regent's-park.* |
| 1811. Dec. 5. | | Locker, Edward Hawke, Esq., F.S.A. *Royal Hospital, Greenwich.* |
| 1841. Nov. 25. | † | Lovelace, William King, Earl of. 10 *St. James's-square; Ockham-park, Ripley, Surrey; and Ashley-combe, Postock, Somerset.* |
| 1834. Dec. 18. | † | Lowe, George, Esq. 39 *Finsbury-circus.* |
| 1810. July 5. | | Lowther, William Viscount, F.S.A. 14 *Carlton-terrace; and Lowther-castle, near Penrith.* |
| 1829. Jan. 15. | | Lubbock, Sir John William, Bart. M.A.—VICE-PRESIDENT.—F.L.S. F.R.A.S. M.R.A.S. 23 *St. James's-place; and High Elms, Farnborough, Kent.* |
| 1826. Feb. 2. | | Lyell, Charles, Jun. Esq., M.A. F.L.S. F.G.S. 16 *Hart-street, Bloomsbury.* |
| 1826. Apr. 13. | | Lyndhurst, John Singleton, Lord, Lord Chancellor, D.C.L. 25 *George-street, Hanover-square.* |
| 1840. Apr. 30. | † | Lyttleton, George William, Lord. 39 *Grosvenor-place; and Hagley-park, near Stourbridge, Worcestershire.* |
| 1843. Feb. 2. | | MacCullagh, James, Esq., D.C.L. Professor of Natural and Experimental Philosophy in the University of Dublin. *Trinity-college, Dublin.* |
| 1816. Mar. 14. | | MacGrigor, Sir James, Bart., F.R.S.E. Coll. Reg. Med. Socius. *Harley-street.* |
| 1815. Apr. 13. | | Mackenzie, Sir George Steuart, Bart. F.R.S.E. *Coul, Ross-shire.* |
| 1817. May 15. | | Mackie, Rev. John William, M.A. 27 *Upper Baker-street.* |
| 1827. June 14. | | Mackinnon, William Alexander, Esq., M.A. F.S.A. F.G.S. 4 *Hyde-park-place; and Newton-park, Lymington, Hants.* |
| 1831. Dec. 8. | | Maclear, Thomas, Esq., F.R.A.S. Astronomer Royal at the Cape of Good Hope. |
| 1809. Jan. 19. | | MacLeay, Alexander, Esq., F.L.S. Acad. Reg. Sc. Holm. Socius, et Acad. Reg. Sc. Taurin. Corresp. *Sydney, New South Wales.* |
| 1839. May 30. | † | Mackmurdo, Gilbert Wakefield, Esq. *St. Thomas's Hospital; and* 7 *New Broad-street.* |
| 1838. April 5. | † | Macneill, Sir John, F.R.A.S. M.R.I.A. 9 *Whitehall-place.* |
| 1832. Feb. 2. | † | Madden, Sir Frederick, K.H. Hon. M.R.I.A. F.S.A. Soc. Reg. Antiq. Septen. Hafn. Socius. *British Museum.* |
| 1817. June 12. | | Maddy, Rev. John, D.D. F.S.A. F.R.A.S. *Somertown, Bury St. Edmunds.* |
| 1819. June 24. | | Magrath, Sir George, K.H. M.D. M.R.I.A. F.L.S. F.G.S. *Plymouth.* |
| 1827. Mar. 22. | † | Mahon, Philip H., Viscount, D.C.L. V.P.S.A. 41 *Grosvenor-place; and Chevening-place, Kent.* |

| Date of Election. | | |
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| 1839. Apr. 18. | † | Maitland, Rev. Samuel Roffy. *Lambeth-palace.* |
| 1829. May 28. | | Maitland, Ebenezer Fuller, Esq., F.S.A. *Henley-on-Thames, Oxfordshire.* |
| 1821. June 28. | * | Majendie, Ashurst, Esq., F.G.S. *Hedingham-castle, Castle Hedingham, Essex.* |
| 1831. May 12. | | Manby, George William, Capt. R.N. *Yarmouth.* |
| 1825. Jan. 20. | | Mangles, James, Esq., Capt. R.N. 66 *Cambridge-terrace, Edgware-road.* |
| 1825. Nov. 24. | | Mantell, Gideon Algernon, Esq., LL.D. F.L.S. F.G.S. Coll. Reg. Med. Socius, Soc. Philom. Paris. Corresp. Acadd. Philad. et Connect., Socius Honor. 19 *Chester-square, Pimlico.* |
| 1836. Jan. 28. | | Marcet, Francis, Esq. *Geneva.* |
| 1816. Mar. 28. | | Markland, James Heywood, Esq., F.S.A. *Bath.* |
| 1819. May 13. | | Marryatt, Frederick, Esq., Capt. R.N. *Wimbledon.* |
| 1845. Feb. 13. | | Martin, James Ranald, Esq., F.R.M. & C.S. M.R.A.S. 71 *A, Grosvenor-street.* |
| 1823. Nov. 27. | | Maskelyne, Anthony Mervin Story, Esq., M.A. *Basset-Down-house, Swindon.* |
| 1832. Feb. 2. | | Mauley, Lord de. 24 *George-street, Hanover-square; and Canford-house, near Wimborne, Dorset.* |
| 1829. Feb. 26. | | Maxwell, John, Esq. *Pollock, Renfrewshire.* |
| 1827. Mar. 1. | † | Mayo, Rev. Charles, B.D. F.S.A. *Colesgrove, near Cheshunt, Hertfordshire.* |
| 1828. Apr. 17. | † | Mayo, Herbert, Esq. |
| 1835. June 4. | † | Mayo, Thomas, M.D. Coll. Reg. Med. Socius. 56 *Wimpole-street.* |
| 1841. Feb. 25. | † | Melbourne, William, Viscount. 39 *South-street, Grosvenor-square; and Brocket-hall, Herts.* |
| 1841. Jan. 14. | † | Melvill, James Cosmo, Esq. *East India House.* |
| 1817. May 15. | | Melville, Robert Viscount, K.T. F.R.A.S. 3 *Somerset-place; and Melville-castle, Edinburgh.* |
| 1838. May 3. | † | Merewether, Very Rev. John, D.D. Dean of Hereford, F.S.A. *Hereford.* |
| 1843. Mar. 9. | † | Miers, John, Esq. *Temple Lodge, Hammersmith.* |
| 1843. Mar. 30. | † | Miller, Joseph, Esq. *Monastery-cottage, East-India-road.* |
| 1827. May 24. | | Miller, Lieut.-Colonel George, C.B. 2 *Stone-buildings, Lincoln's-inn.* |
| 1845. Feb. 6. | | Miller, William Allen, M.D. Professor of Chemistry, King's College, London. *King's College.* |
| 1838. Feb. 8. | | Miller, William Hallows, Esq. M.A. Professor of Mineralogy. *Cambridge.* |
| 1836. Mar. 3. | | Minto, Gilbert Elliot Murray Kynynmound, Earl of, F.R.A.S. *Minto-castle, Roxburghshire.* |
| 1835. Nov. 26. | | Molesworth, Sir William, Bart. 1 *Lowndes-square; and Pencarrow, Cornwall.* |
| 1841. Apr. 29. | † | Monteagle, Thomas, Lord. 37 *Lower Brook-street; and Exchequer-office, Whitehall.* |
| 1845. Feb. 13. | † | Monteith, Major-General William. *Wilmington, Dartford.* |
| 1836. June 16. | | Montefiore, Sir Moses, Knt. 7 *Grosvenor-gate, Park-lane; and East Cliff-lodge, Ramsgate.* |
| 1806. May 6. | | Moore, Major Edward, F.S.A. M.R.A.S. *Bealings, near Woodbridge, Suffolk.* |
| 1835. April 2. | † | Moore, George, Esq., F.S.A. F.L.S. 64 *Lincoln's-inn-fields.* |
| 1827. Feb. 8. | | Moreau, César, Esq. Acadd. Reg. Divion., Burd., et Masil., Socius. *Paris.* |
| 1835. April 2. | † | Morgan, Arthur, Esq. 26 *New Bridge-street, Blackfriars.* |
| 1816. May 30. | | Morgan, Charles, Esq., F.S.A. 70 *Pall-mall; and Tredegar-house, near Newport, Monmouthshire.* |
| 1832. Feb. 2. | † | Morgan, Octavius S., Esq. M.A. F.S.A. 70 *Pall-mall; and Tredegar-park, Monmouthshire.* |
| 1819. Feb. 4. | | Morier, James, Esq. 22 *Charles-street, Berkeley-square.* |

| Date of Election. | |
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| 1831. Mar. 10. | Morris, John Carnac, Esq. |
| 1842. Mar. 3. | † Morison, Major-General William, C.B. F.R.S.E. *Oriental-club, or 16 Saville-row.* |
| 1839. Feb. 7. | † Moseley, Rev. Henry, M.A. *Wandsworth.* |
| 1830. Feb. 18. | Moss, Joseph William, M.B. *Dudley.* |
| 1822. Dec. 5. | Mudge, Rich. Zachariah, Esq., Lieut.-Col. R.E. *Beechwood, Plympton, Devon.* |
| 1826. April 6. | Murchison, Roderick Impey, Esq., M.A. Hon. M.R.I.A. V.P.G.S. F.L.S. Inst. Reg. Sc. Paris. et Acad. Reg. Taurin. Corresp., et Soc. Imp. Sc. Nat. Hist. Mosq. Socius. Vice-President of the Royal Geographical Society. 16 *Belgrave-square.* |
| 1805. July 4. | Murdoch, Thomas, Esq., F.S.A. 8 *Portland-place.* |
| 1823. June 19. | Murray, Right Hon. Sir George, G.C.B. G.C.H. K.T.S. 5 *Belgrave-square; and Bleaden, Perthshire.* |
| 1826. Mar. 16. | Mylne, William Chadwell, Esq., F.R.A.S. *New-River-head.* |
| 1817. June 12. | Napier, Macvey, Esq., F.R.S.E. *Edinburgh.* |
| 1840. June 18. | † Narrien, John, Esq., F.R.A.S., Professor of Mathematics in the Royal Military College, Sandhurst. *Sandhurst.* |
| 1814. May 5. | Neave, Sir Thomas, Bart. F.S.A. 6 *Albemarle-street; and Dagenham-park, Rumford, Essex.* |
| 1842. Jan. 6. | Newbold, Thomas John, Esq., Lieut. E.I.C.S. *Madras.* |
| 1833. Feb. 7. | † Nolan, Rev. Frederick, LL.D. M.R.S.L. *Prittlewell, Essex.* |
| 1842. Dec. 15. | Norfolk, The Most Noble Howard, Duke of. 1 *Hyde-park-place.* |
| 1830. May 27. | Northampton, Spencer Joshua Alwyne, Marquis of.—PRESIDENT.—Trust. Brit. Mus. F.S.A. Hon. M.R.I.A. F.L.S. F.G.S. 145 *Piccadilly; and Castle Ashby, Northampton.* |
| 1823. May 1. | Northumberland, Hugh, Duke of, K.G. M.A. Trust. Brit. Mus. F.S.A. F.L.S. F.G.S. *Northumberland-house, Strand.* |
| 1840. June 4. | † Norwich, Edward Stanley, Lord Bishop of, President of the Linnean Society. 38 *Lower Brook-street; and Palace, Norwich.* |
| 1826. Feb. 2. | † Ogle, James Adey, M.D. F.R.A.S. Coll. Reg. Med. Socius. Lord Lichfield's, and Aldrich's Professor of Medicine, Oxford. |
| 1786. Nov. 16. | Oldershaw, Venerable John, B.D. Archdeacon of Norfolk. *Harlestone, Norfolk.* |
| 1835. June 4. | Oliveira, Benjamin, Esq., F.S.A. 8 *Upper Hyde-park-street.* |
| 1824. Mar. 4. | Orford, Horatio, Earl of. *White's Club; and Wolterton-park, Norfolk.* |
| 1819. Feb. 25. | Ormerod, George, Esq., D.C.L. F.S.A. F.G.S. *Sudbury-park, Gloucestershire.* |
| 1843. Mar. 16. | † O'Shaughnessy, William Brooke, Esq., M.D. *Calcutta.* |
| 1838. May 3. | Outram, Benjamin Fonseca, M.D. F.R.G.S. 1 *Hanover-square.* |
| 1834. Dec. 18. | Owen, Richard, Esq., M.D. F.L.S. V.P.G.S. Instit. Sc. Paris. Corresp. Fellow and Hunterian Professor of Anatomy and Physiology in the Royal College of Surgeons of England. *Royal College of Surgeons, Lincoln's-inn-fields.* |
| 1821. Nov. 15. | Palgrave, Sir Francis, K.H. Deputy Keeper of Her Majesty's Records. *Rolls'-yard, Chancery-lane; and Hampstead-green.* |
| 1821. June 21. | * Paris, John Ayrton, M.D. President of the Royal College of Physicians. 28 *Dover-street.* |
| 1824. Mar. 4. | Parish, Sir Woodbine, K.C.H. F.S.A. F.G.S. *Naples.* |
| 1815. June 1. | Parker, Thomas Lister, Esq., F.S.A. 34 *Mount-street.* |
| 1840. Feb. 6. | † Parkinson, John, Esq., F.L.S. 80 *Cambridge-terrace, Hyde-park.* |

| Date of Election. | | |
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| 1812. Feb. 20. | | Parry, Charles Henry, M.D. *Bath.* |
| 1821. Feb. 15. | | Parry, Sir William Edward, Knt. D.C.L. Capt. R.N. Hon. M.R.I.A. F.R.A.S. Acad. Imp. Sc. Petrop. Socius, Inst. Reg. Sc. Paris. 22 *New-street, Spring-gardens.* |
| 1837. Feb. 23. | † | Partridge, Richard, Esq. 17 *New-street, Spring-gardens.* |
| 1816. Mar. 7. | | Pasley, Major-General Charles William, R.E. C.B. F.R.A.S. F.G.S. *Board of Trade, Whitehall;* 12 *Norfolk-crescent, Hyde-park.* |
| 1818. Jan. 29. | | Peacock, Very Rev. George, D.D. Dean of Ely.—VICE-PRESIDENT.—F.G.S. F.R.A.S. *Deanery, Ely.* |
| 1833. Dec. 5. | | Pearson, Sir Edwin, K.H. M.A. 5 *Gloucester-terrace, Regent's-park.* |
| 1819. July 1. | | Pearson, Rev. William, LL.D. F.R.A.S. *South Kilworth, near Welford, Northamptonshire.* |
| 1826. Mar. 9. | | Pearson, Sir William, Knt. M.D. 16 *Hanover-square.* |
| 1832. Feb. 2. | | Pechell, Sir Samuel John Brooke, Bart. Capt. R.N. 27 *Hill-street, Berkeley-square.* |
| 1822. Dec. 5. | | Peel, Right Hon. Sir Robert, Bart. D.C.L. Trust. Brit. Mus. F.S.A. *Whitehall-gardens; and Drayton-Manor, Fazeley, Staffordshire.* |
| 1835. April 2. | † | Pelly, Sir John Henry, Bart. *Trinity-house.* |
| 1813. Feb. 11. | | Pemberton, George, Esq. *Bainbridge Holme, Durham; and* 9 *Mortimer-street, Cavendish-square.* |
| 1827. May 24. | | Pendarves, Edward William Wynne, Esq., M.A. F.G.S. 36 *Eaton-place, Belgrave-sq.; and Pendarves, Truro, Cornwall.* |
| 1824. Nov. 18. | | Penn, Richard, Esq. 6 *Whitehall.* |
| 1808. Jan. 28. | | Pepys, William Hasledine, Esq., F.L.S. 22 *Poultry.* |
| 1838. May 3. | † | Pereira, Jonathan, M.D. F.L.S. 47 *Finsbury-square.* |
| 1807. Dec. 10. | | Petit, Louis Hayes, Esq., M.A. F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.S.L. 9 *New-square, Lincoln's-inn.* |
| 1817. Mar. 6. | | Petre, William Francis Henry, Lord. 3 *Mansfield-street; and Thorndon-hall, near Brentwood, Essex.* |
| 1827. Feb. 1. | † | Pettigrew, Thomas Joseph, Esq., F.S.A. M.R.A.S. Univ. Gotting. Phil. Doct.—Acad. Reg. Divion. Socius. 8 *Saville-row.* |
| 1826. Apr. 11. | | Philip, Alexander Philip Wilson, M.D. Coll. Reg. Med. Socius. F.R.S.E. |
| 1840. Feb. 13. | † | Phillimore, Joseph, LL.D. 15 *College, Doctor's-commons; and* 22 *Portman-street.* |
| 1819. Jan. 29. | | Phillipps, Sir Thomas, Bart. M.A. F.S.A. F.G.S. Hon. M.R.S.L. *Middle-hill, Worcestershire.* |
| 1834. Dec. 18. | | Phillips, Benjamin, Esq. 17 *Wimpole-street, Cavendish-square.* |
| 1834. Apr. 10. | † | Phillips, John, Esq., Prof. F.G.S. *York.* |
| 1822. Mar. 14. | * | Phillips, Richard, Esq., F.R.S.E. 6 *Craig's-court, Charing-cross; and Camberwell-green.* |
| 1791. Mar. 10. | | Pocock, Sir George, Bart. *Bransgore-house, Ringwood, Hampshire.* |
| 1829. April 9. | | Pole, William, Esq. M.A. 66 *Brook-street.* |
| 1829. April 9. | | Pollock, David, Esq., F.R.A.S. M.R.A.S. M.R.S.L. 20 *Montague-street, Russell-square; and* 3 *Pump-court, Temple.* |
| 1816. Feb. 29. | | Pollock, The Right Hon. Sir Frederick, Chief Baron of the Exchequer, K.H. M.A. F.S.A. F.G.S. *Queen-square-house, Guildford-street.* |
| 1838. Jan. 18. | † | Porter, George Richardson, Esq., M.R.A.S. Instit. Reg. Sc. Paris. Corresp. *Board of Trade, Whitehall.* |
| 1837. June 8. | | Portlock, Joseph Ellison, Esq., Capt. R.E. F.G.S. *Cork.* |
| 1824. May 13. | | Powell, Rev. Baden, M.A. F.R.A.S. Savilian Professor of Geometry, Oxford. *Oxford.* |

| Date of Election. | | |
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| 1842. Jan. 27. | † | Pratt, Samuel Peace, Esq., F.L.S. F.G.S. 55 *Lincoln's-inn-fields; and Bath.* |
| 1827. Feb. 8. | | Prichard, James Cowles, M.D. Hon. M.R.I.A. Instit. Reg. Sc. Paris. Corresp. 1 *Woburn-place, Russell-square.* |
| 1840. Feb. 6. | † | Pritchard, Rev. Charles, M.A. *Clapham.* |
| 1819. Mar. 11. | * | Prout, William, M.D. Coll. Reg. Med. Socius. 40 *Sackville-street,* |
| 1818. April 9. | | Prudhoe, Algernon, Lord, F.S.A. President of the Royal Institution of Great Britain. *Whitehall-gardens; and Stanwick-park, Darlington, Yorkshire.* |
| 1830. May 27. | | Pusey, Philip, Esq. 35 *Grosvenor-square; and Pusey-house, near Faringdon, Berks.* |
| 1844. Feb. 29. | † | Quain, Richard, Esq. Professor of Anatomy, University College, London. 23 *Keppel-st.* |
| 1814. Dec. 15. | | Rashleigh, William, Esq., F.L.S. 3 *Cumberland-terrace, Regent's-park; and Menabilly-house, Foy, Cornwall.* |
| 1837. Jan. 19. | † | Rastrick, John Urpath, Esq. 46 *Eaton-square.* |
| 1838. Feb. 8. | | Reade, Rev. Joseph Bancroft, M.A. *Stone Vicarage, Aylesbury.* |
| 1843. Feb. 2. | | Rees, George Owen, M.D. F.G.S. Coll. Reg. Med. Socius. 59 *Guildford-st, Russell-sq.* |
| 1817. June 12. | | Reeves, John, Esq., F.L.S. F.R.A.S. *Clapham.* |
| 1834. Feb. 6. | | Reeves, John Russell, Esq., F.L.S. *Clapham.* |
| 1839. Feb. 21. | † | Reid, Lieut.-Colonel William, C.B. R.E. Governor of Bermuda. |
| 1843. Feb. 23. | † | Rendel, James Meadows, Esq. 34 *Great George-street, Westminster.* |
| 1822. Mar. 21. | | Rennie, George, Esq.—Vice-President and Treasurer.—Hon. M.R.I.A. 21 *Whitehall-place.* |
| 1823. June 12. | | Rennie, Sir John, Knt. President of the Institution of Civil Engineers. 15 *Whitehall-pl.* |
| 1845. May 22. | | Rennie, James, Esq. 6 *Whitehall-place.* |
| 1825. Feb. 24. | | Richardson, John, M.D. F.L.S. Acad. Sc. Nat. Philad., Georg. Paris. Corresp.—Socc. Hist. Nat. Montreal, Lit. et Phil. Quebec, Hist. Nat. Boston, Socius Honor. *Haslar-hospital, Gosport.* |
| 1840. April 2. | † | Richmond, Charles Gordon Lennox, Duke of, K.G. President of the Royal Agricultural Society. 51 *Portland-place; and Goodwood, near Petworth, Sussex.* |
| 1820. Mar. 23. | | Ricketts, Charles Milner, Esq., F.G.S. *Lima.* |
| 1842. Jan. 13. | | Riddell, Charles James Buchanan, Esq., Lieut. R.A. *Woolwich.* |
| 1839. Apr. 25. | | Rigg, Robert, Esq. *Greenford, Middlesex.* |
| 1828. Apr. 17. | | Ripon, Frederick John, Earl of. 4 *St. James's-square.* |
| 1836. Feb. 11. | | Robertson, Archibald, M.D. *Northampton.* |
| 1796. Nov. 17. | | Rogers, Samuel, Esq. F.S.A. 22 *St. James's-place.* |
| 1839. Dec. 5. | | Rogers, John, jun. Esq. *Vine-lodge, near Sevenoaks, Kent.* |
| 1815. Mar. 16. | | Roget, Peter Mark, M.D.—Secretary.—F.G.S. F.R.A.S. V.P.S.A. Coll. Reg. Med. Socius. 18 *Upper Bedford-place, Russell-square.* |
| 1844. Feb. 1. | † | Ronalds, Francis, Esq. *Chiswick.* |
| 1831. June 9. | | Ros, Hon. I. Frederick F. de, Capt. R.N. F.R.A.S. 116 *Piccadilly.* |
| 1834. June 5. | | Rose, Sir George, Knt. 4 *Hyde-park-gardens.* |
| 1819. April 1. | | Rosebery, Archibald John, Earl of, K.T. 139 *Piccadilly; and Dalmeney-park, Linlithgow.* |
| 1822. June 13. | | Ross, Captain Daniell. *India.* |
| 1828. Dec. 11. | | Ross, Sir James Clark, Knt. Capt. R.N. D.C.L. F.L.S. F.R.A.S. Soc. Reg. Sc. Hafn. Socius. *Aston House, Aston Abbots, Aylesbury.* |
| 1831. Dec. 8. | | Rosse, William, Earl of, F.R.A.S. *Birr-castle, King's-county, Ireland.* |
| 1839. Dec. 12. | † | Roupell, George Leith, M.D. 15 *Welbeck-street.* |

| Date of Election. | | |
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| 1837. April 6. | † | Royle, John Forbes, M.D. F.L.S. F.G.S. F.R.A.S. Professor of Materia Medica and Therapeutics, King's-college. 4 *Bulstrode-street, Manchester-square.* |
| 1805. Jan. 31. | | Rudge, Edward, Esq., F.S.A. F.L.S. F.H.S. F.R.G.S. 44 *Wimpole-street; and Abbey Manor-house, Evesham, Worcestershire.* |
| 1821. June 7. | | Russell, Jesse Watts, D.C.L. F.S.A. F.L.S. F.G.S. *Ilam-hall, Staffordshire.* |
| 1818. Apr. 16. | | Sabine, Lieut.-Colonel Edward, R.A.—Foreign Secretary.—F.R.A.S. Acadd. Imp. Sc. Petrop., Reg. Sc. Taur., Brux., Norv. Phil. et Œcon. Siles. Socius: Socc. Reg. Sc. Gotting., Mem. National Inst. Washington U.S. et Geogr. Paris., Corresp. *Athenæum Club; and Woolwich.* |
| 1832. Dec. 6. | | Sandford, Edward Ayshford, Esq. *Nynehead, Somerset.* |
| 1833. Apr. 18. | † | Saunders, Rev. Augustus Page, D.D. *Charterhouse-school.* |
| 1822. June 27. | | Sawbridge, Henry Barne, Esq. |
| 1824. June 17. | | Scoresby, Rev. William, D.D. F.R.S.E. Instit. Reg. Sc. Paris. Corresp. Vicar of Bradford, Yorkshire. *Bradford.* |
| 1800. Jan. 16. | | Scott, John Corse, Esq. *Edinburgh.* |
| 1826. Dec. 7. | | Scrope, George Poulett, Esq., F.G.S. 13 *Belgrave-square; and Castle Combe, Chippenham, Wiltshire.* |
| 1824. Jan. 15. | † | Scudamore, Sir Charles, Knt. M.D. 6 *Wimpole-street.* |
| 1821. Feb. 1. | | Sedgwick, Rev. Adam, M.A. Hon. M.R.I.A. F.G.S. F.R.A.S. Woodwardian Lecturer. *Cambridge.* |
| 1831. Jan. 13. | | Selkirk, Thomas James, Earl of. *St. Mary's Isle, Kirkcudbright.* |
| 1841. June 17. | † | Seymour, Edward James, M.D. Coll. Reg. Med. Socius. 13 *Charles-street, Berkeley-square.* |
| 1840. May 7. | † | Sharp, William, Esq., F.G.S. F.R.A.S. *Humber-bank-house, Hull.* |
| 1839. May 9. | | Sharpey, William, M.D. F.R.S.E. Professor of Anatomy in University-college. 35 *Gloucester-crescent, Regent's-park.* |
| 1831. Apr. 21. | | Shee, Sir Martin Archer, Knt. President of the Royal Academy. 32 *Cavendish-square.* |
| 1830. April 1. | | Sheepshanks, Rev. Richard, M.A. F.G.S. F.R.A.S. 14 *London-road, Reading.* |
| 1824. Mar. 11. | | Shuckburg, Sir Francis, Bart. *Pavilion, Hans-place, Chelsea; and Shuckburg-park, Warwickshire.* |
| 1841. Mar. 4. | † | Siever, Robert William, Esq. 12 *Henrietta-street, Cavendish-square.* |
| 1813. Mar. 11. | | Simmons, Richard, Esq., F.S.A. F.L.S. 3 *Cumberland-place, Regent's-park.* |
| 1845. Jan. 9. | | Simon, John, Esq., Demonstrator of Anatomy, King's College. 11 *Wellington-street.* |
| 1837. Apr. 20. | † | Skey, Frederic Carpenter, Esq. 13 *Grosvenor-street.* |
| 1820. Mar. 23. | | Sleath, Rev. John, D.D. F.S.A. 4 *Hertford-street, May-fair.* |
| 1841. June 10. | | Smee, Alfred, Esq. 7 *Finsbury-circus.* |
| 1824. May 14. | | Smith, Lieut.-Col. Charles Hamilton, F.L.S. *Plymouth.* |
| 1830. Dec. 23. | | Smith, James, Esq., F.R.S.E. *Jordan-hill, near Glasgow.* |
| 1837. June 1. | | Smith, John T., Esq., Capt. Madras Engineers. *Madras.* |
| 1840. Jan. 9. | † | Smith, Rev. John Pye, D.D. LL.D. F.G.S. Prof. Div. and President of the Protestant Dissenting College, Homerton. *Homerton, Middlesex.* |
| 1803. May 10. | | Smith, John Spenser, Esq., F.S.A. *Caen, Normandy.* |
| 1819. Nov. 25. | | Smith, Joseph, Esq., F.L.S. 1 *Field-court, Gray's-inn.* |
| 1806. Feb. 13. | | Smith, Sir William, Knt. |
| 1841. Nov. 18. | † | Smith, Sir J. M. Frederic, Lieut. Colonel R.E. *Chatham.* |

| Date of Election. | |
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| 1826. June 15. | Smyth, William Henry, Esq., Capt. R.N. K.S.F. D.C.L. Hon. M.R.I.A. F.S.A. Pres. R.A.S.—Instit. Reg. Sc. Paris. Corresp., Acadd. Sc. Neap., Panorm. et Flor., Socius, Corresp. Mem. National Inst. Washington and Naval Lyceum of New York, 2 *Cheyne-walk, Chelsea.* |
| 1843. Jan. 19. | † Solly, Edward, Esq., F.L.S. 38 *Bedford-row.* |
| 1807. May 7. | * Solly, Richard Horsman, Esq., M.A. F.S.A. F.L.S. F.G.S. 48 *Great Ormond-street.* |
| 1812. May 14. | Solly, Samuel, Esq., F.L.S. 48 *Upper Gower-street ; and Poole, Dorset.* |
| 1837. Jan. 19. | † Solly, Samuel, Esq. 1 *St. Helen's-place, Bishopsgate-street.* |
| 1823. May 29. | Solly, Samuel Reynolds, Esq., M.A. F.S.A. F.G.S. *Surge-hill, King's Langley, Herts.* |
| 1797. Mar. 9. | Somerset, Edward Adolphus, Duke of, K.G. D.C.L. F.S.A. F.L.S. *Park-lane.* |
| 1817. Dec. 11. | Somerville, William, M.D. F.R.S.E. F.L.S. F.G.S. *Rome.* |
| 1845. June 5. | Sopwith, Thomas, Esq., F.G.S. *Newcastle-on-Tyne.* |
| 1821. Feb. 15. | South, Sir James, Knt. F.R.S.E. Hon. M.R.I.A. F.L.S. F.R.A.S. Acad. Imp. Sc. Petrop. Socius.—Acad. Reg. Sc. Brux. Corresp. *The Observatory, Camden-hill, Kensington.* |
| 1825. Apr. 14. | Southey, Henry Herbert, M.D. Coll. Reg. Med. Socius. 1 *Harley-street.* |
| 1834. Apr. 10. | † Spence, William, Esq., F.L.S. Soc. Linn. Holm. Soc. 18 *Lower Seymour-street.* |
| 1844. Feb. 1. | † Stanford, John Frederick, Esq., M.A. *Foley-house, Portland-place.* |
| 1807. Jan. 8. | * Stanhope, Philip Henry, Earl. 20 *Charles-street, Berkeley-sq.; and Chevening-place, Kent.* |
| 1816. June 27. | Stanhope, John Spencer, Esq. |
| 1830. Mar. 11. | Stanley, Edward, Esq. 23 *A, Brook-street.* |
| 1790. Apr. 29. | Stanley, John Thomas, Lord, F.S.A. 40 *Dover-street, Piccadilly.* |
| 1842. Mar. 3. | Stanley, Owen, Esq., Capt. R.N. |
| 1803. Apr. 28. | Staunton, Sir George Thomas, Bart. D.C.L. M.P. F.S.A. F.L.S. 17 *Devonshire-street, Portland-place.* |
| 1845. Apr. 3. | † Stebbing, Rev. Henry, D.D. F.R.B.S. *Residence, St. James's-chapel, Hampstead-road.* |
| 1832. April 5. | † Stephens, Archibald John, Esq., M.A. 61 *Chancery-lane ; and 43 Torrington-square.* |
| 1829. Jan. 15. | Steuart, John Robert, Esq., M.R.A.S. 56 *North Frederick-street, Edinburgh.* |
| 1811. Nov. 21. | Stevenson, William Ford, Esq., F.S.A. *Grande-rue, Passy, near Paris.* |
| 1838. May 3. | Stirling, Edward Hamilton, Esq. *Calcutta.* |
| 1821. Jan. 18. | Stokes, Charles, Esq., F.S.A. F.L.S. F.G.S. F.R.A.S. 4 *Verulam-buildings, Gray's-inn.* |
| 1810. June 7. | Stracey, Sir Edward, Bart. LL.D. *Rackheath-hall, Norfolk.* |
| 1825. Feb. 3. | Strangford, Percy Clinton, Sydney, Viscount, G.C.B. G.C.H. D.C.L. F.S.A. 68 *Harley-street.* |
| 1821. Mar. 8. | Strangways, Hon. William Thomas Horner Fox. 31 *Old Burlington-street ; and Abbotsbury, Dorsetshire.* |
| 1832. June 7. | † Stratford, William Samuel, Esq., Lieut. R.N. F.R.A.S. Superintendent of the Nautical Almanac. 6 *Notting-hill-square, Kensington.* |
| 1796. Nov. 17. | Sumner, George Holme, Esq., F.S.A. *Hatchlands, Guildford, Surrey.* |
| 1828. Mar. 13. | Sutherland, Alexander Robert, M.D. Coll. Reg. Med. Socius, F.G.S. 1 *Parliament-street ; and Torquay.* |
| 1820. Dec. 14. | Swainson, William, Esq., F.L.S. Soc. Hist. Nov.-Ebor. Socius.—Soc. Hist. Nat. Paris. Corresp. *New Zealand.* |
| 1839. Mar. 14. | † Swanston, Clement Tudway, Esq., F.S.A. 51 *Chancery-lane.* |
| 1818. Feb. 26. | Swinburne, Sir John Edward, Bart. F.S.A. 18 *Grosvenor-place.* |

| Date of Election. | |
|---|---|
| 1834. Feb. 6. | † Sykes, Lieut.-Colonel William Henry, Hon. M.R.I.A. F.G.S. M.R.A.S. 47 *Albion-street, Hyde-park.* |
| 1839. Apr. 25. | † Sylvester, James Joseph, Esq., M.A. F.R.A.S. 26 *Lincoln's-inn-fields.* |
| 1835. June 4. | † Symonds, Sir William, K.H. Capt. R.N. 4 *Somerset-place.* |
| 1813. May 6. | Talbot, Charles Chetwynd, Earl, K.P. F.S.A. *Ingestrie-hall, near Stafford; and* 10 *Great George-street.* |
| 1831. Mar. 17. | Talbot, Christopher Rice Mansel, Esq. *Margam, Glamorganshire.* |
| 1831. Mar. 17. | Talbot, William Henry Fox, Esq., F.L.S. 31 *Sackville-street; and Lacock-abbey, near Chippenham.* |
| 1835. Feb. 5. | † Tattam, Rev. Henry, D.D. M.A. M.R.S.L. *Bedford.* |
| 1845. Nov. 20. | † Taylor, Alfred Swaine, Esq., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital. 3 *Cambridge-place, Regent's-park.* |
| 1825. May 5. | Taylor, John, Esq., Treas. G.S. F.L.S. *Sheffield-house, Church-street, Kensington.* |
| 1842. Feb. 10. | Taylor, Thos. Glanville, Esq., F.R.A.S. Astronomer to the East India Company. *Madras.* |
| 1836. Jan. 21. | † Taylor, Rev. William. 77 *Westbourne-terrace, Hyde-park.* |
| 1834. June 5. | Teignmouth, Charles John, Lord, D.C.L. 19 *Portland-place.* |
| 1833. Dec. 5. | Terry, Charles, Esq., F.S.A. |
| 1845. June 19. | Thesiger, Sir Frederick, Attorney-General. 11 *Bryanston-square; and* 2 *King's-bench-walk, Temple.* |
| 1806. Jan. 16. | Thomas, Honoratus Leigh, Esq. *Torquay.* |
| 1828. Nov. 20. | Thompson, Lieut.-Colonel Thomas Perronet, M.A. *Eliot-vale, Blackheath.* |
| 1821. Dec. 20. | Thomson, James, Esq., F.L.S. *Primrose, near Clitheroe.* |
| 1824. June 3. | Thomson, John, M.D. F.R.S.E. *Edinburgh.* |
| 1811. Mar. 28. | Thomson, Thomas, M.D., Regius Professor of Chemistry, Glasgow, Hon. M.R.I.A. F.R.S.E. F.L.S. F.G.S. *Glasgow.* |
| 1810. June 7. | Thornton, Right Hon. Edward, G.C.B. *Wembury-house, Plymouth.* |
| 1834. Apr. 10. | † Thornton, Henry Sykes, Esq., M.A. *Battersea-rise, Surrey.* |
| 1839. May 30. | † Thorp, The Venerable Charles, D.D. Archdeacon of Durham and Warden of the University of Durham. *Durham.* |
| 1841. Feb. 25. | † Tierney, Rev. Mark Aloysius. *Arundel, Sussex.* |
| 1835. April 2. | Tite, William, Esq., F.S.A. 25 *Upper Bedford-place.* |
| 1838. Feb. 8. | † Todd, Robert Bentley, M.D. Coll. Reg. Med. Socius, Professor of Physiology and General Anatomy, King's College, London. 26 *Parliament-street.* |
| 1821. Mar. 22. | Tooke, Thomas, Esq. 31 *Spring-gardens.* |
| 1818. Mar. 12. | Tooke, William, Esq., M.R.S.L. 12 *Russell-square.* |
| 1818. Dec. 17. | * Torrens, Lieut.-Colonel Robert. *Reform Club, Pall-mall.* |
| 1812. Dec. 17. | * Towneley, Peregrine Edward, Esq., Trust. Brit. Mus. F.S.A. 7 *Park-street, Westminster; and Towneley-hall, near Burnley, Lancashire.* |
| 1842. Nov. 17. | Towneley, Charles, Esq. 3 *Tilnay-street, Park-lane.* |
| 1822. Nov. 7. | Townley, George, Esq. 5 *L, Albany.* |
| 1842. Mar. 10. | Toynbee, Joseph, Esq. 12 *Argyll-place.* |
| 1823. May 29. | Traherne, Rev. John Montgomery, M.A. F.S.A. F.L.S. F.G.S. *St. Hilary, near Cowbridge, Glamorganshire.* |
| 1815. Nov. 16. | Travers, Benjamin, Esq. 12 *Bruton-street.* |
| 1822. Nov. 14. | Tulk, Charles Augustus, Esq., F.S.A. *Totteridge-park, Herts.* |

| Date of Election. | |
|---|---|
| 1843. May 18. | Tulloch, James, Esq., F.S.A. F.L.S. 16 *Montague-place, Bedford-square.* |
| 1845. Apr. 10. | † Tupper, Martin Farquhar, Esq., M.A. *Furze-hill, Brighton; and Albury, Surrey.* |
| 1817. June 5. | Turnbull, Peter Evans, Esq., F.S.A. |
| 1831. Mar. 17. | Turnbull, Rev. Thomas Smith, M.A. F.G.S. *Caius College, Cambridge.* |
| 1821. May 24. | Turner, Charles Hampden, Esq., F.L.S. F.G.S. 15 *Bruton-street; and Rook's-nest-park, Godstone, Surrey.* |
| 1802. Dec. 9. | Turner, Dawson, Esq., Hon. M.R.I.A. F.S.A. F.L.S. M.R.S.L. Acadd. Cæs. Nat. Cur. et Reg. Sc. Holm. Socius. *Athenæum Club; and Yarmouth.* |
| 1815. Dec. 21. | Turner, Samuel, Esq. *Liverpool.* |
| 1839. May 9. | † Turnor, Rev. Charles, M.A. F.S.A. F.R.A.S. *Cheltenham.* |
| 1838. April 5. | † Tuson, Edward William, Esq., F.L.S. 10 *Russell-place, Fitzroy-square.* |
| 1838. Feb. 8. | † Tweedie, Alexander, M.D. Coll. Reg. Med. Socius. 30 *Montague-place, Bedford-square.* |
| 1834. June 5. | Twining, Richard, Esq. 13 *Bedford-place, Russell-square.* |
| 1838. Mar. 15. | † Twiss, Travers, Esq., D.C.L. F.G.S. Professor of Political Economy in the University of Oxford. 5 *B, Albany, Piccadilly.* |
| 1820. Apr. 13. | Tylden, Lieut.-Colonel Sir John Maxwell, Knt. *Milsted, Kent.* |
| 1821. Dec. 13. | Ure, Andrew, M.D. F.R.A.S. 13 *Charlotte-street, Bedford-square.* |
| 1813. June 24. | Vaughan, William, Esq. 70 *Fenchurch-street.* |
| 1830. May 6. | Vetch, Capt. James, R.E. F.G.S. Corresp. Mem. Natt. Inst. Washington, U.S. *Truro.* |
| 1823. Jan. 9. | Vivian, John Henry, Esq., F.G.S. 2 *Upper Belgrave-square; and Swansea, Glamorganshire.* |
| 1826. June 8. | Vyvyan, Sir Richard Rawlinson, Bart. *Trelowarren, Cornwall.* |
| 1828. Apr. 17. | Walker, James, Esq., F.R.S.E. 23 *Great George-street, Westminster.* |
| 1831. Mar. 3. | Walker, Rev. Robert, M.A. Reader in Experimental Philosophy in the University of Oxford. *Wadham College, Oxford.* |
| 1830. April 1. | Wall, Charles Baring, Esq., M.A. F.S.A. M.R.S.L. 44 *Berkeley-square; and Norman-court, near Stockbridge, Hampshire.* |
| 1829. Mar. 12. | Wallich, Nathaniel, M. et Ph.D. F.R.S.E. F.L.S. F.G.S. M.R.A.S. Instit. Reg. Sc. Paris., et Acad. Reg. Sc. Berolin., Corresp.—Soc. Reg. Sc. Hafn. Socius. *Calcutta.* |
| 1819. Nov. 11. | Walter, Rev. Henry, B.D. *Hasilbury Brian, Dorsetshire.* |
| 1837. May 25. | † Walton, Rev. William, M.A. *Allenheads, Northumberland.* |
| 1809. Feb. 16. | Warburton, Henry, Esq., M.A. 45 *Cadogan-place, Sloane-street.* |
| 1834. Apr. 10. | Warburton, John, M.D. Coll. Reg. Med. Socius. 23 *Park-crescent, Regent's-park.* |
| 1817. May 1. | Warre, John Ashley, Esq. 54 *Lowndes-square, Sloane-street.* |
| 1830. Dec. 9. | Warren, Rev. John, M.A. *Graveley, Cambridgeshire.* |
| 1835. April 2. | † Warren, Samuel, Esq. *Inner Temple; and* 35 *Woburn-place.* |
| 1815. June 8. | Warrender, Right Hon. Sir George, Bart. F.R.S.E. |
| 1845. Feb. 13. | † Washington, John, Esq., Capt. R.N. F.G.S. M.R.G.S. A.I.C.E. |
| 1834. Feb. 6. | Waterhouse, John, jun., Esq. *Halifax, Yorkshire.* |
| 1818. Nov. 12. | Watson, Sir Frederick Beilby, K.C.H. F.S.A. 4 *Albany-terrace, New-road.* |
| 1820. Dec. 7. | Watt, James, Esq. *Aston-hall, Birmingham.* |
| 1827. May 24. | † Wavell, Major-General Arthur Goodall, K.F. K.C.S. |
| 1826. Mar. 9. | Weaver, Thomas, Esq., M.R.I.A. F.G.S. 16 *Stafford-row, Pimlico; and Woodlands, Wrington.* |
| 1822. Mar. 21. | Webb, Frederick, Esq., F.S.A. *Langham-place, Brighton.* |
| 1844. Mar. 7. | Webster, John, M.D. Coll. Reg. Med. Socius. 24 *Brook-street, Grosvenor-square.* |

| Date of Election. | |
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| 1837. May 25. | † Westmacott, Richard, Esq., F.G.S. 21 *Wilton-place, Belgrave-square.* |
| 1824. Dec. 16. | Wetherell, Sir Charles, Knt. D.C.L. 5 *Stone-buildings, Lincoln's-inn.* |
| 1814. June 9. | Weyland, John, Esq. 52 *Charles-street, Berkeley-square; and Woodrising-hall, Norfolk.* |
| 1840. Jan. 9. | Whatman, James, jun., Esq. *Vinters, near Maidstone, Kent.* |
| 1836. Jan. 21. | † Wheatstone, Charles, Esq., Professor of Experimental Philosophy, King's College, London, Instit. Reg. Sc. Paris. Corresp. 20 *Conduit-street.* |
| 1820. Apr. 13. | Whewell, Rev. William, B.D. Hon. M.R.I.A. F.S.A. F.G.S. F.R.A.S. Master of Trinity College, Cambridge. *Lodge, Cambridge.* |
| 1837. Apr. 13. | † White, William Archibald Armstrong, Esq., F.S.A. 14 *College-street, Westminster.* |
| 1842. Dec. 22. | † Widdrington, Samuel E., Esq., Capt. R.N. *Carlton-hall, near Darlington; and Newton-hall, Northumberland.* |
| 1835. April 2. | † Wigram, Hon. Sir James, Knt. M.A. F.S.A. 68 *Portland-place.* |
| 1821. Mar. 8. | Wilbraham, George, Esq. *Delamere-house, Northwich, Cheshire.* |
| 1834. Dec. 18. | Wilkinson, Sir John Gardner, Knt. 34 *Conduit-street.* |
| 1835. April 2. | † Williams, Charles James Blasius, M.D. Coll. Reg. Med. Socius, Professor of Physic in University College, London. 7 *Holles-street, Cavendish-square.* |
| 1828. Mar. 6. | Williams, John, jun., Esq., F.L.S. *Scorrier-house, near Redruth, Cornwall.* |
| 1830. Apr. 22. | Willis, Rev. Robert, M.A. F.G.S. Jacksonian Professor of Natural and Experimental Philosophy. *Cambridge.* |
| 1812. May 7. | Wilmot, Sir John Eardley Eardley, Bart. D.C.L. F.S.A. F.L.S. Governor of Van Diemen's Land. |
| 1838. Mar. 1. | † Wilson, Alexander, Esq. 34 *Bryanston-square.* |
| 1845. Feb. 6. | Wilson, Erasmus, Esq., Lecturer on Anatomy and Physiology, Middlesex Hospital. 55 *Upper Charlotte-street, Fitzroy-square.* |
| 1801. Apr. 16. | Wilson, Sir Giffin, Knt. 2 *Stratford-place; and Woburn-house, Beaconsfield, Buckinghamshire.* |
| 1796. Apr. 28. | Wilson, Glocester, Esq. *Hastings.* |
| 1834. Apr. 10. | Wilson, Horace Hayman, Esq., M.A. M.R.A.S. Boden Professor of Sanscrit in the University of Oxford. 14 *Upper Wimpole-street.* |
| 1845. Feb. 6. | † Wilson, Rev. John, D.D. M.R.A.S. Hon. Pres. Bombay Branch of the R.A.S. *Bombay.* |
| 1834. June 5. | Witt, George, M.D. *Bedford.* |
| 1813. Feb. 25. | Wix, Rev. Samuel, M.A. F.S.A. *Rectory-house, St. Bartholomew's the Less.* |
| 1810. July 12. | Wix, William, Esq. *Tunbridge-wells, Kent.* |
| 1829. Feb. 26. | Wollaston, Alexander Luard, Esq., M.B. F.R.A.S. |
| 1812. Dec. 24. | * Wood, William, Esq., F.L.S. *Ruislip, near Uxbridge.* |
| 1836. Dec. 22. | † Wood, William Page, Esq. 3 *Stone-buildings, Lincoln's-inn.* |
| 1841. May 20. | † Wood, Lieut.-Colonel Thomas. 4 *Cavendish-square.* |
| 1841. Apr. 29. | † Woodward, Charles, Esq. 10 *Compton-terrace, Islington.* |
| 1829. June 4. | Wortley, Hon. John Stuart, B.A. 15 *Curzon-street, May-fair.* |
| 1843. June 1. | † Wright, Rev. John, M.A. F.S.A. F.R.A.S. M.R.S.L. 67 *Westbourne-terrace, Hyde-park-gardens; and The Vicarage, Malvern.* |
| 1841. Apr. 29. | † Wrottesley, John, Lord.—VICE-PRESIDENT. *Wrottesley-hall, Wolverhampton.* |
| 1839. Jan. 31. | † Yates, James, Esq., M.A. F.L.S. F.G.S. 49 *Upper Bedford-place; and Norton-hall, Derbyshire.* |

# FOREIGN MEMBERS.

| | | |
|---|---|---|
| Louis Agassiz | *Neufchatel.* | 1838. |
| François-Jean-Dominique Arago | *Paris.* | 1818. |
| Elie de Beaumont | *Paris.* | 1835. |
| Antoine César Becquerel | *Paris.* | 1837. |
| Jens Jacob Berzelius | *Stockholm.* | 1813. |
| Friedrich Wilhelm Bessel | *Königsberg.* | 1825. |
| Jean-Baptiste Biot | *Paris.* | 1815. |
| H. M. Ducrotay de Blainville | *Paris.* | 1832. |
| Alexandre Brongniart | *Paris.* | 1815. |
| Leopold von Buch | *Berlin.* | 1828. |
| Francesco Carlini | *Milan.* | 1832. |
| Augustin-Louis Cauchy | *Paris.* | 1832. |
| Michel-Eugène Chevreul | *Paris.* | 1826. |
| Le baron de Damoiseau | *Paris.* | 1832. |
| Jean-Baptiste Dumas | *Paris.* | 1840. |
| Christian Gottfried Ehrenberg | *Berlin.* | 1837. |
| Johann Friedrich Encke | *Berlin.* | 1825. |
| Paul Erman | *Berlin.* | 1827. |
| P. Flourens | *Paris.* | 1835. |
| Karl Friedrich Gauss | *Göttingen.* | 1804. |
| P. A. Hansen | *Seeberg.* | 1835. |
| Christopher Hansteen | *Christiana.* | 1839. |
| Baron Alexander von Humboldt | *Berlin.* | 1815. |
| C. G. J. Jacobi | *Königsberg.* | 1833. |
| Admiral A. I. von Krusenstern | *St. Petersburgh.* | 1837. |
| Baron von Liebig | *Giessen.* | 1840. |
| Baron von Lindenau | *Dresden.* | 1833. |
| Henry Frederic Link | *Berlin.* | 1842. |
| Joseph-Louis Gay-Lussac | *Paris* | 1815. |
| Carl. Fried. Philip von Martius | *Munich.* | 1838. |
| Macédonie Melloni | *Parma.* | 1839. |
| C. F. Brisseau Mirbel | *Paris.* | 1837. |
| Eilert Mitscherlich | *Berlin.* | 1828. |
| Johann Müller | *Berlin.* | 1840. |
| Jens Christian Oersted | *Copenhagen.* | 1821. |
| George Simon Ohm | *Nuremberg.* | 1842. |
| Giovanni Plana | *Turin.* | 1827. |
| Jean Victor Poncelet | *Paris.* | 1842. |
| G. de Pontécoulant | *Paris.* | 1833. |
| Lambert Adolphe Jacques Quetelet | *Brussels.* | 1839. |
| Henry Rose | *Berlin.* | 1842. |
| O. A. Rosenberger | *Halle.* | 1835. |
| Heinrich Christian Schumacher | *Altona.* | 1821. |
| Friedrich Georg Wilhelm Struve | *Dorpat.* | 1827. |
| Jacques Charles François Sturm | *Paris.* | 1840. |
| Le baron Thénard | *Paris.* | 1824. |
| Friedrich Tiedemann | *Heidelberg.* | 1832. |

## FELLOWS DECEASED SINCE THE LAST ANNIVERSARY (Nov. 30, 1844).

### *On the Home List.*

David Francis Atcherley, Esq.
George Basevi, Esq.
George Henry Law, Lord Bishop of Bath and Wells.
Rev. William Frederick Baylay.
John Laurens Bicknell, Esq.
Samuel Bosanquet, Esq.
Right Hon. William Sturges Bourne.
Rev. Henry Coddington.
John Frederic Daniell, Esq., For. Secretary.
Very Rev. Edmund Goodenough, Dean of Wells.
William Heberden, M.D.
Thomas Phillips, Esq., R.A.
John Ramsbottom, Esq.
Martin Tupper, Esq,
The Marquis of Westminster, K.G.
Sir Isaac Wilson, Knt., M.D.

### *On the Foreign List.*

Le Comte de Cassini.
Théodore de Saussure.

### *Ceased to be Fellows in default of their Annual Payments.*

Robert Grymbald Bigsby, Esq.
Rev. George Glover, Archdeacon of Sudbury.
Henry Napier, Esq., Capt. R.N.

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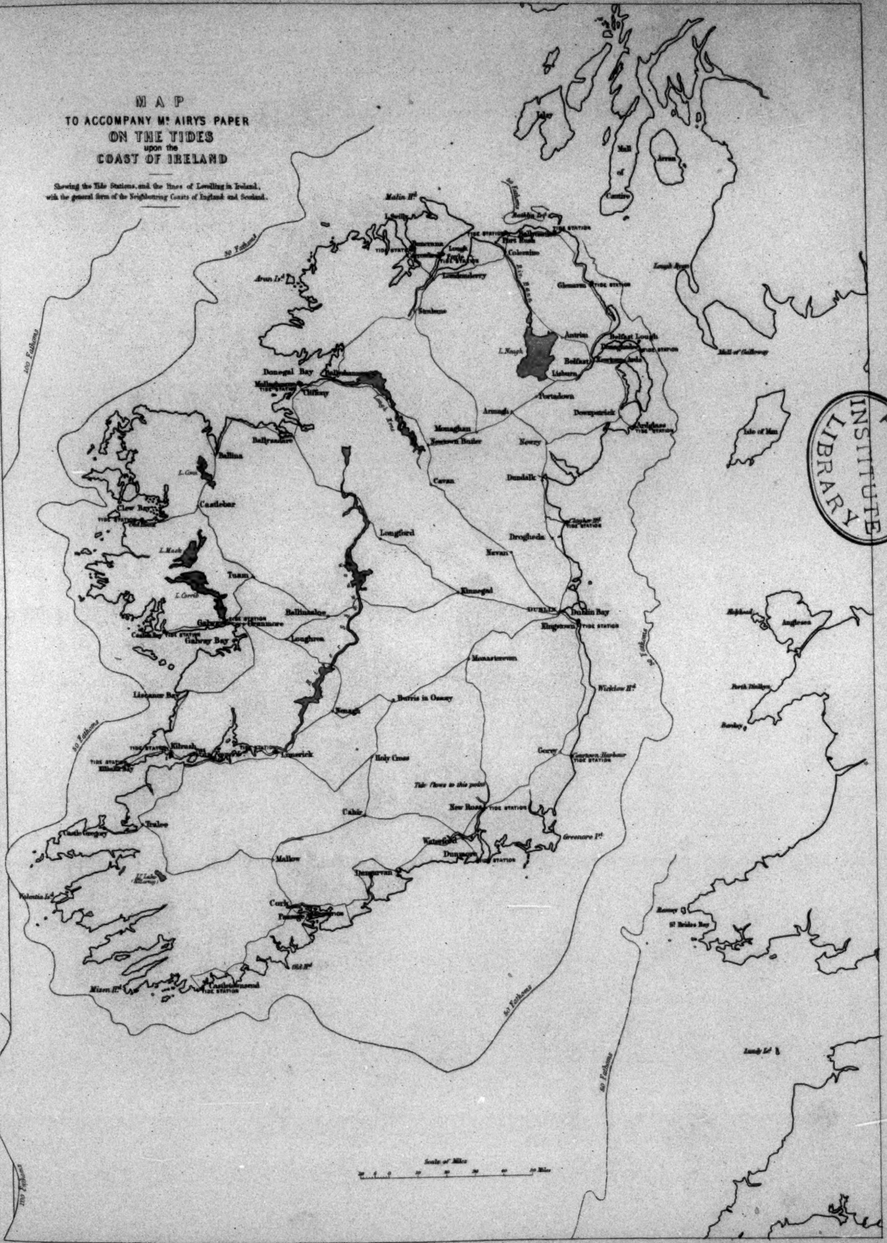
## FELLOWS ADMITTED SINCE THE LAST ANNIVERSARY (Nov. 30, 1844).

### *On the Home List.*

| Date of Election. | |
|---|---|
| 1845. June 5. | Adair, Robert Shafto, Esq. |
| 1845. June 5. | Bandon, Right Hon. the Earl of. |
| 1845. Nov. 20. | Barlow, Peter William, Esq. |
| 1844. Dec. 12. | Barrow, John, jun., Esq. |
| 1845. Mar. 6. | Dickenson, John, Esq. |
| 1845. Feb. 13. | Falconer, Hugh, M.D. |
| 1845. Feb. 13. | Forbes, Edward, Esq. |
| 1845. Feb. 13. | Fownes, George, Esq. |
| 1845. May 8. | Harrison, Thomas Charles, Esq. |
| 1845. April 3. | Jackson, Colonel Julius. |
| 1845. June 5. | Johnston, Alexander Robert, Esq. |
| 1845. Feb. 13. | Martin, James Ranald, Esq. |
| 1845. Feb. 6. | Miller, William Allen, M.D. |
| 1845. Feb. 13. | Monteith, Major-Gen. William. |
| 1845. May 29. | Rennie, James, Esq. |
| 1845. Jan. 9. | Simon, John, Esq. |
| 1845. June 5. | Sopwith, Thomas, Esq. |
| 1845. April 3. | Stebbing, Rev. Henry, D.D. |
| 1845. Nov. 20. | Taylor, Alfred Swaine, Esq. |
| 1845. June 19. | Thesiger, Sir Frederick. |
| 1845. Apr. 10. | Tupper, Martin Farquhar, Esq. |
| 1845. Feb. 13. | Washington, John, Esq., Capt. R.N. |
| 1845. Feb. 20. | Wilson, Erasmus, Esq. |
| 1845. Feb. 6. | Wilson, Rev. John, D.D. |

100 Fathoms



# MAP
## TO ACCOMPANY M^r. AIRY'S PAPER
# ON THE TIDES
## upon the
# COAST OF IRELAND

Showing the Tide Stations, and the lines of Levelling in Ireland, with the general form of the Neighbouring Coasts of England and Scotland.

Islay
Mull of Cantire
Arran
Rathlin Isd.
Malin Hd.
Tide Station
Ballycastle
Port Rush
Coleraine
Lough Foyle
Tide Station
Londonderry
Aran Isd.
Strabane
Glenarm
Tide Station
Lough Ryan
Mull of Galloway
L. Neagh
Antrim
Belfast Lough
Belfast
Tide Station
Lisburn
Portadown
Armagh
Downpatrick
Ardglass
Tide Station
Isle of Man
Donegal Bay
Ballyshannon
Tide Station
Cliffony
Lough Erne
Monaghan
Newtown Butler
Newry
Ballyrassure
Ballina
L. Conn
Cavan
Dundalk
Clogher Hd.
Tide Station
Castlebar
Clew Bay
Tide Station
Longford
Drogheda
L. Mask
Navan
Tuam
L. Corrib
Kinnegad
Ballinasloe
Dublin
Dublin Bay
Galway
Tide Station
Oranmore
Tide Station
Galway Bay
Loughrea
Kingstown
Tide Station
Holyhead
Anglesea
Monasterevan
Wicklow Hd.
Liscanor Bay
Nenagh
Borris in Ossory
Porth Dinllaen
Bardsey
Kilrush
Tide Station
Tide Station
Kilbaha Bay
Limerick
Tide Station
Holy Cross
Gorey
Courtown Harbour
Tide Station
Tide flows to this point
New Ross
Tide Station
Cahir
Tralee
Castle Gregory
Waterford
Dunmore
Tide Station
Greenore Pt.
Mallow
Upr. Lake (Killarney)
Dungarvan
Valentia Isd.
Cork
Passage
Ramsey
St. Brides Bay
Old Hd.
Mizen Hd.
Castletownsend
Tide Station
Lundy Isd.
50 Fathoms
50 Fathoms
50 Fathoms
50 Fathoms
50 Fathoms
50 Fathoms
100 Fathoms
100 Fathoms
Scale of Miles
10 0 10 20 30 40 50 Miles

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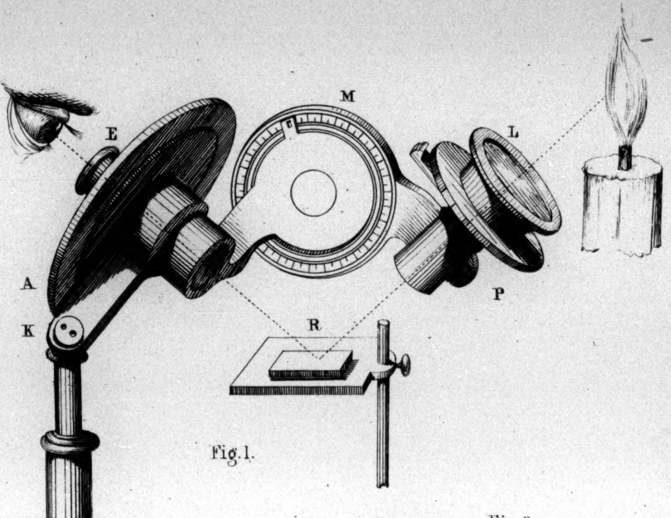
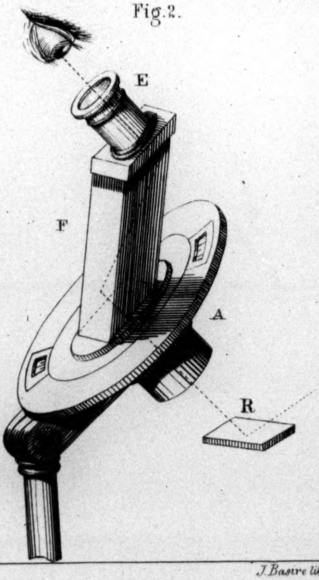


Fig. 1.

Fig. 2.



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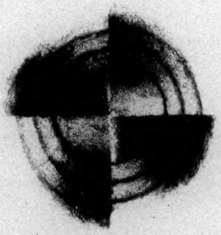

*J. Basire lith.*

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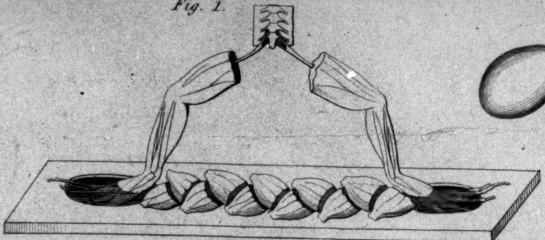

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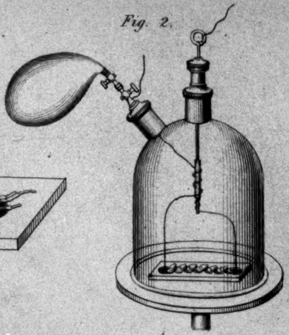

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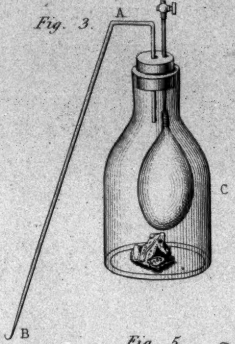

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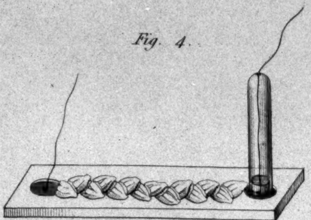

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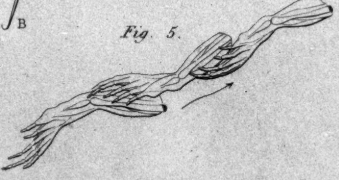

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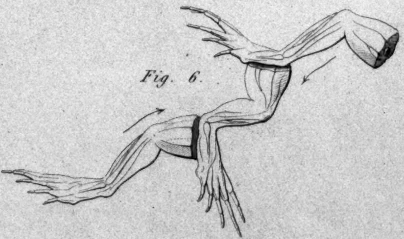

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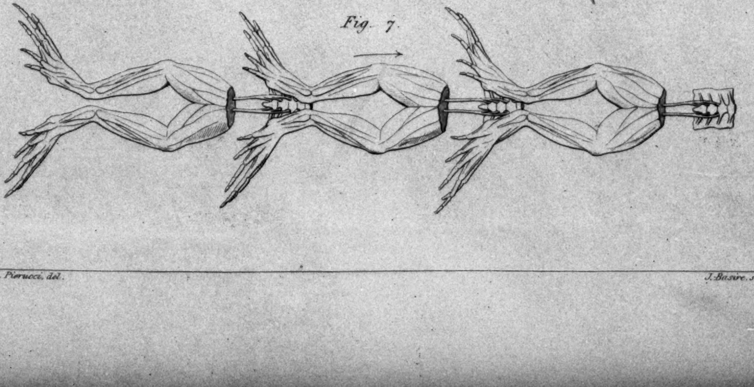

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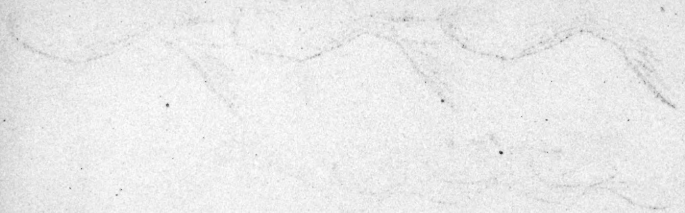

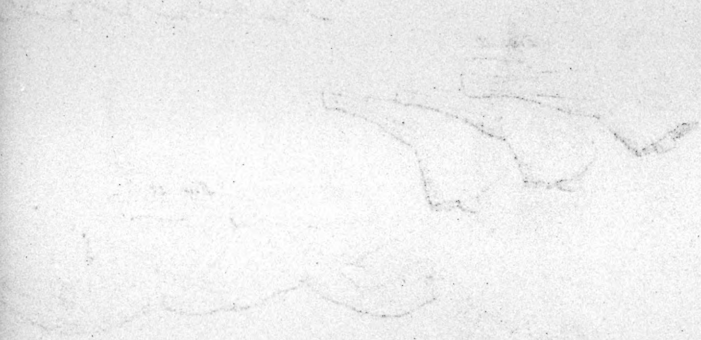

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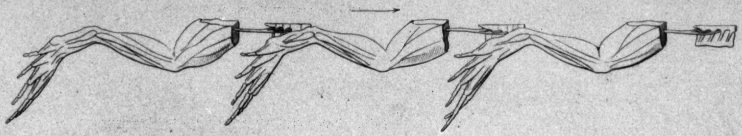

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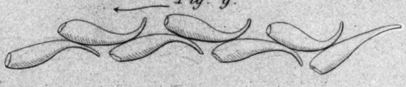

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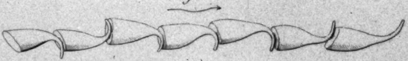

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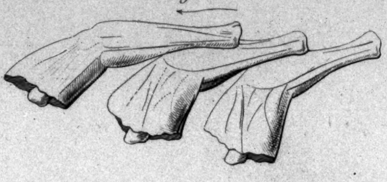

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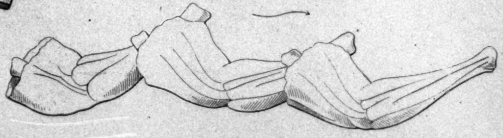

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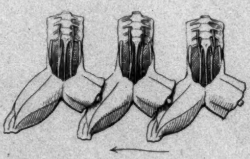

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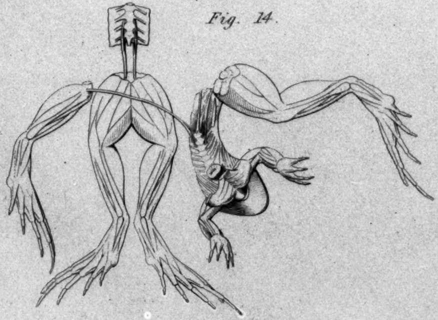
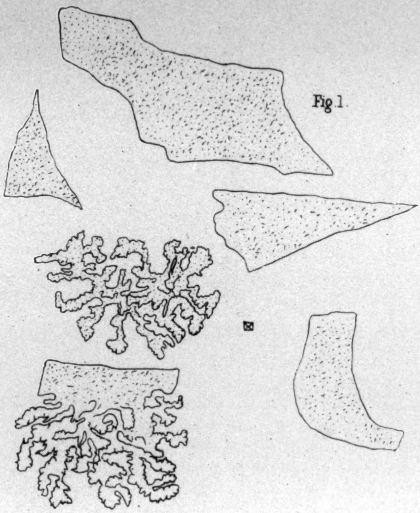


Fran. Pierucci, del.

J. Basire, sc.



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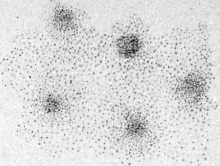

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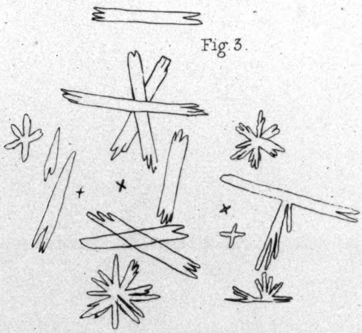

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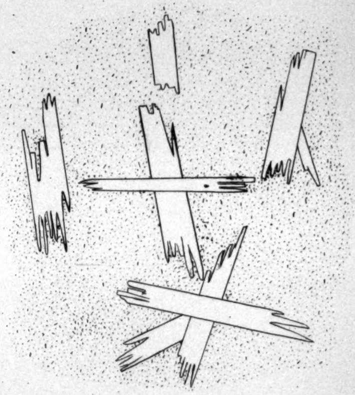

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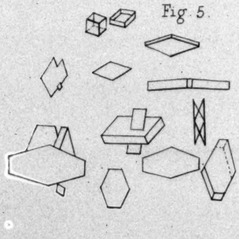

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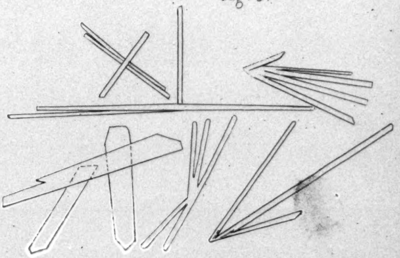
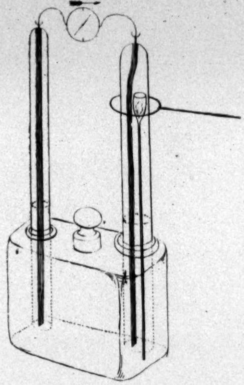


Fig. 6.

J. Basire, lith.

Phil. Trans. MDCCCXLV. Plate VI. p. 352.

Fig. 2.



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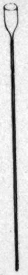

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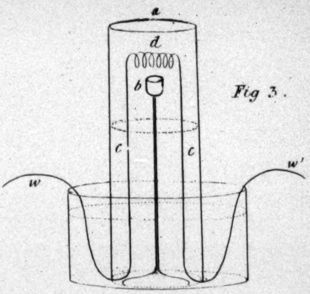

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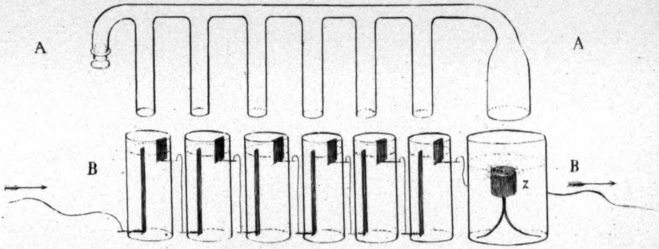

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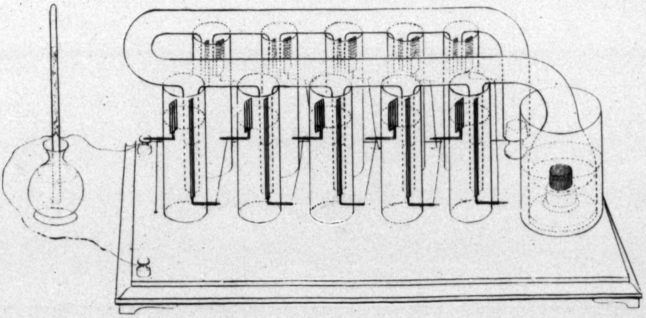

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